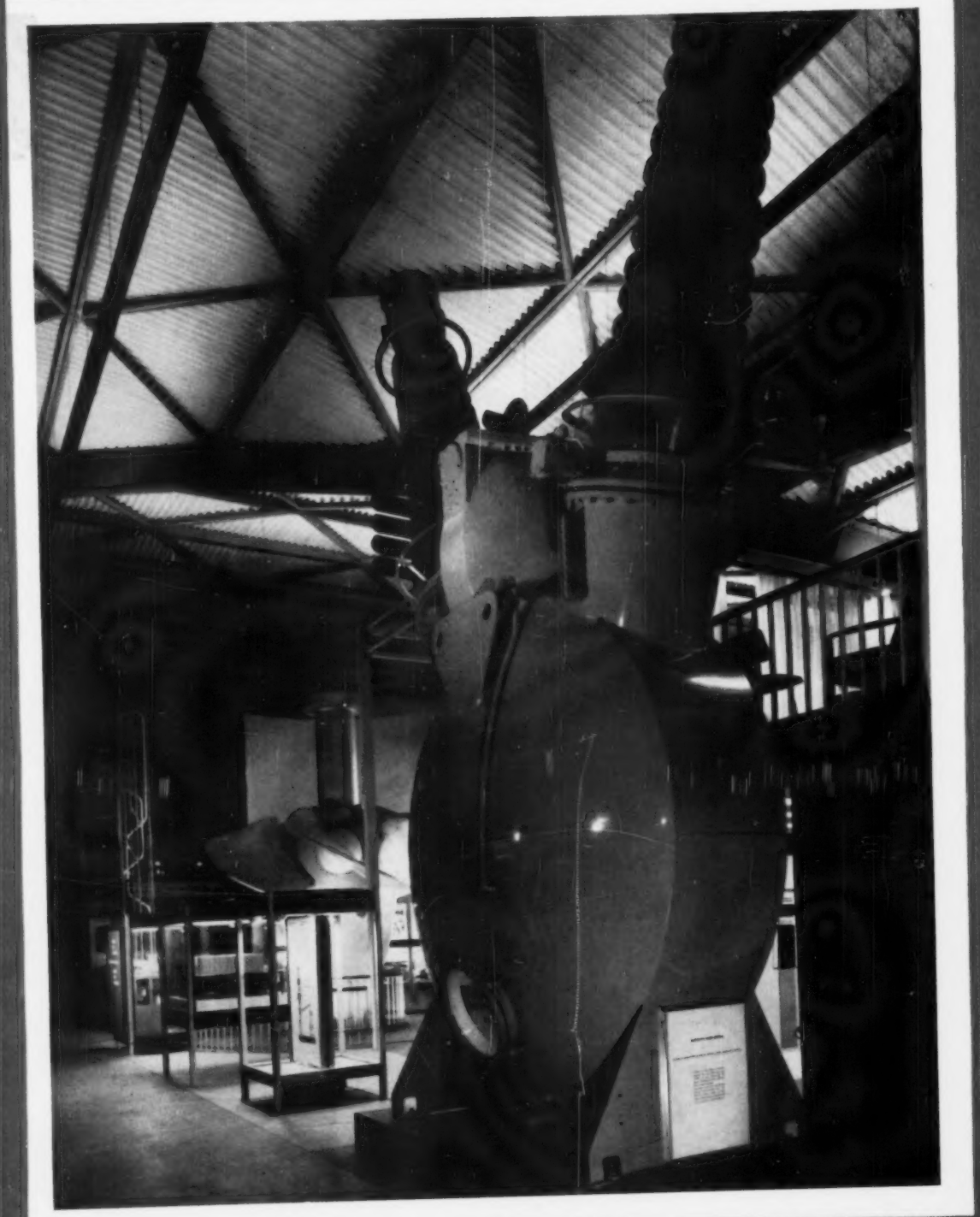
MAY 1958

THE BEAMA JOURNAL



A QUARTERLY REVIEW OF

BRITISH ELECTRICAL AND ALLIED ENGINEERING

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A QUARTERLY REVIEW OF BRITISH ELECTRICAL AND ALLIED ENGINEERING

Volume 65 : Number 2 : May 1958

Editorial

Standard Screw Threads for Normal Production

In January of this year, member-firms of the British Electrical and Allied Manufacturers' Association received a letter from the Director embodying the advice of the BEAMA Council and its Standardization Committee on the question of screw thread practice for normal production. This move prompted a widespread demand for copies of the letter, which set out the carefully considered reasons for the Association's opinion that the electrical and allied industries should continue to use the British Standard Whitworth and BA threads as their normal production practice. So great was the demand that the BEAMA Council decided to issue the letter in booklet form.

Any move to abandon those thread systems at the present time could have a profound effect on the long-term interests both of the electrical industry and its customers all over the world, and the demand for copies of the BEAMA booklet is clear evidence of a general need for considered guidance on this question.

The original proposals for a unified screw thread system based on American practice arose from war-time discussions between the Defence Services of America, Britain, and Canada, and the outcome was the issue in 1949 of British Standard 1580: Unified Screw Threads. In 1952 it was announced that the Defence Services had decided to adopt this thread, and the BEAMA's recommendation to its members was then—and still is—that they should cooperate with the Services by supplying the unified thread for their special requirements.

The suitability of this thread as standard production practice for the home and export markets of British industry is, however, an entirely different matter.

In general, the Whitworth screw thread system has not only been the normal production practice in the United Kingdom, the Commonwealth, and a number of European countries, but it has a usage as wide as, if not wider than, any other thread throughout the world. Moreover, there is so far no indication from established UK markets that it is any less acceptable now than it has been in the past.

The International Standards Organization set up its Screw Thread Committee in 1946 to reach agreement on a recommendation for a world standard screw thread system, and it was found that a majority of countries were not prepared to accept a unified screw thread system based on American national standards. The Whitworth thread was not put forward for consideration. The ISO is now proposing to recommend two systems—one based on the American inch system, and the other a metric system. Supporters of the latter may well be influenced by the current problems arising from the projected economic integration of European countries, and by the recent adoption of metric systems by some far-eastern countries.

The ISO has not yet published its detailed recommendations, but until such time as it is possible to foresee which other system is likely to be more generally acceptable than the present British practice, the BEAMA Council has given a clear lead to its member-firms by advising the continued use of British Standard Whitworth and BA threads in order to maintain the advantages of a standard interchangeable production practice throughout the industry.

It should be emphasized that this policy is not prompted either by prejudice or narrow-minded nationalism. The criterion for the normal production practice of an industry is quite simple: it is the practice that results in the minimum number of 'special requirements'. As the second largest exporting industry of the UK, the British electrical and allied industry would welcome agreement on one world standard screw thread system, provided there is a reasonable certainty that it would become more generally acceptable than the present British standards. If the situation is to be further complicated by the recommendation of *two* world standards, it would then remain to be seen which of the three systems the majority of the overseas markets would prefer: the existing system or either of the two new systems. Until this happens and sufficiently clear indications emerge, British industry would find it unwise to make any premature change in its current practice. Already there are indications that engineers abroad, where Whitworth and BA threads have

long been supplied and accepted, are critical when they find that some items of equipment in a composite installation supplied by British manufacturers use a different thread.

Equipment for the Services, and for the few overseas markets where Whitworth and BA threads are not the generally accepted standards, are special cases needing individual consideration according to circumstances and the needs of the customer for a departure from normal British standards. But the requirements for efficient production, in the best interests of the industry and its customers in overseas and home markets alike, surely indicate the wisdom of a conservative policy in maintaining one interchangeable normal production practice until a new system emerges which meets with an acceptance at least as wide as the long-established British production practice.

Brussels and the 1958 British Electrical Conference

The opening of the Brussels World Exhibition of 1958 enables us to publish in this issue the first pictorial record of the impressive exhibit of the British Electrical and Allied Industry—the largest single exhibit in the British Pavilion. Occupying as it does some 5000 square feet (565 m^2), it is impossible to portray the whole of this comprehensive exhibit in one photograph. The record therefore concentrates on a series of pictures of each section which, viewed in conjunction with the artist's impression published in our last issue, gives a representative survey of the wide range of the industry's activities and products and their uses all over the world.

For those who will be unable to visit the Exhibition before it closes on 19 October, this pictorial record and the special publications produced for Brussels will convey a graphic impression of the enterprise, resources, and technical skill of the British electrical and allied industry.

This issue also includes a report of the British Electrical Conference at Brussels on 16 and 17 May. This—the only British conference to be held during the run of the Exhibition—was organized by the British Electrical and Allied Manufacturers' Association, and THE BEAMA JOURNAL is therefore able to publish the complete text, with illustrations, of the important papers presented at the Conference by Sir Gordon Radley and Sir John Cockcroft.

Here, for all to read, are two more chapters in the impressive story of British scientific and engineering achievements and their influence on world progress.

Zeta and Sceptre

It was not possible in our last issue to do more than record briefly the world-wide announcement of the triumph of British scientists in achieving the successful control of thermo-nuclear fusion—the goal towards which the world's leading atomic physicists have been striving for many years.

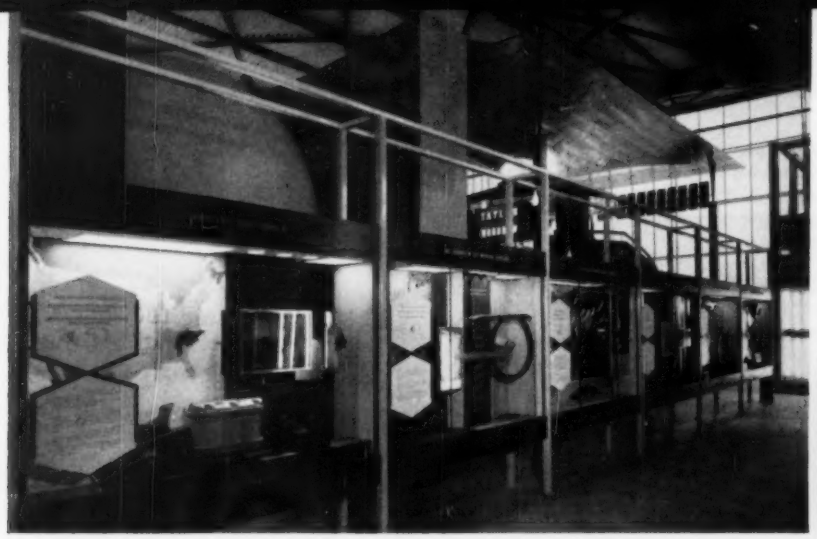
Its attraction lies in the fact that it holds the key to the ultimate possibility of deriving unlimited power from the cheapest and most plentiful of all the world's natural sources—sea water. Faced with the exhaustion in a finite length of time of the natural stores of fossil fuel, and even of the known sources of uranium—at present the most plentiful and cheapest fuel for fission reactors—it is not surprising that nuclear fusion has captured the imagination of scientists and laymen alike, and, as so often happens in such cases, has occasioned comments and forecasts which have been more optimistic than the present stage of scientific knowledge and technical achievement would justify.

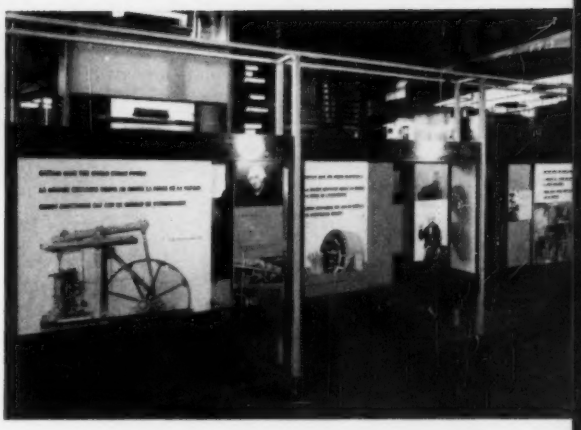
That the fusion of deuterium nuclei has taken place at temperatures of the order of 5 million degrees C, thereby releasing free neutrons, seems to have been established beyond reasonable doubt, although Sir John Cockcroft himself and the teams of scientists under Dr Thoneman at Harwell and Dr Allibone at Aldermaston will not at present go further than saying that they are at least 90 per cent certain that the observed emission of free neutrons has been brought about by thermo-nuclear fusion and that the reaction is in line with theoretical expectations. Complete confirmation—of the kind to satisfy the scientific mind—must await the next stage of development and the achievement of still higher temperatures for longer periods than the present few microseconds. This work is being energetically pursued at both establishments: Harwell, which is the Research Establishment of the UK Atomic Energy Authority; and Aldermaston, the Research Laboratories of Associated Electrical Industries Ltd. Although working independently, there has been close and constant collaboration between these two groups, who are the main teams working on controlled thermo-nuclear research in this country.

Reduced to its simplest terms, the problem is that of raising the temperature of the gas used (either deuterium or deuterium and tritium) to a sufficiently high temperature—100 million degrees C or more—and for sufficiently long periods so as to get out of the equipment more energy than has to be put in to bring about the reaction.

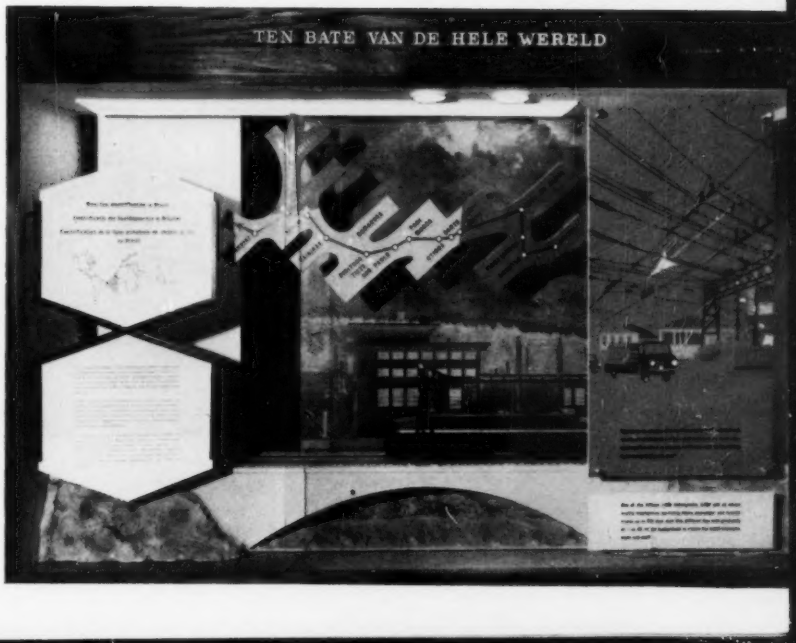
No one—not even the scientists most closely concerned—will venture to forecast a time-table. That the road will be long and arduous is certain; anything from twenty years or more is possible. Even though short-cuts may later be discovered, it seems unlikely, in the light of present knowledge, that power from thermo-nuclear fusion will supplant fission power on a commercial scale until long after the cost of the new fission reactors now being built has been written off.

Cover illustration. *One of the many striking features in the British Electrical and Allied Industry's exhibit at the Brussels Exhibition is this large oil-filled circuit-breaker which dominates one end of the stand. More pictures of the exhibit appear on pages 47 to 50.*





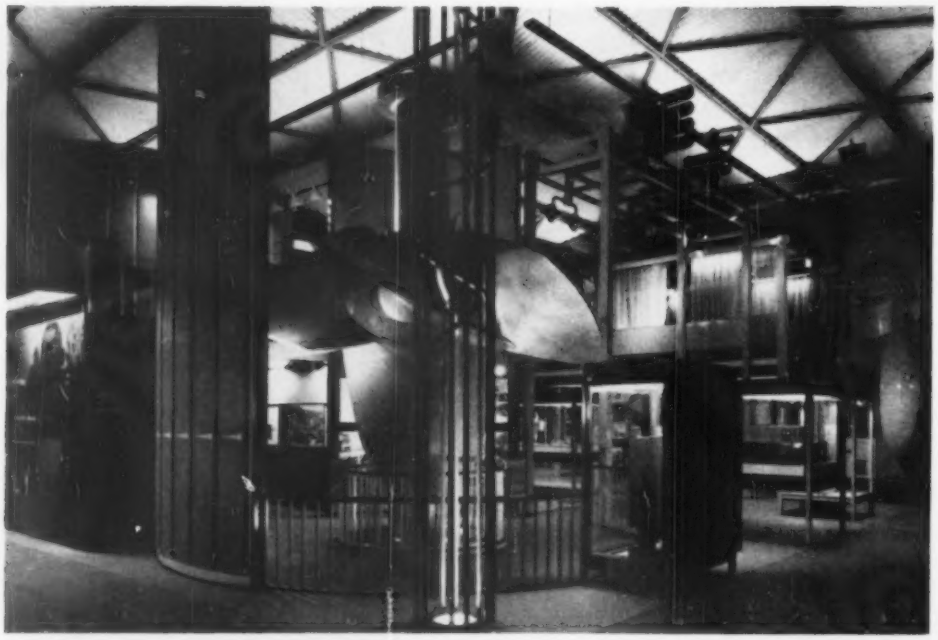
This four-page pictorial feature and the photograph on the front cover are designed to give a general impression of the British Electrical and Allied Industry's exhibit at Brussels. The photographs are representative of the many full-sized equipments, scale models, dioramas and pictorial features which make up the wide variety and scope of this comprehensive exhibit

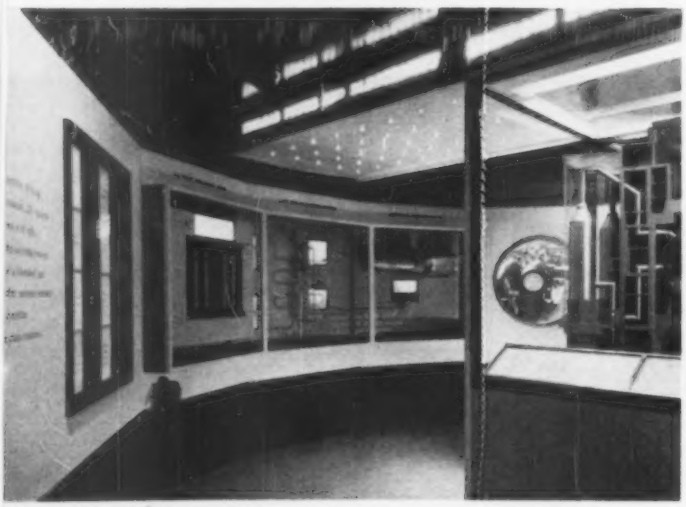


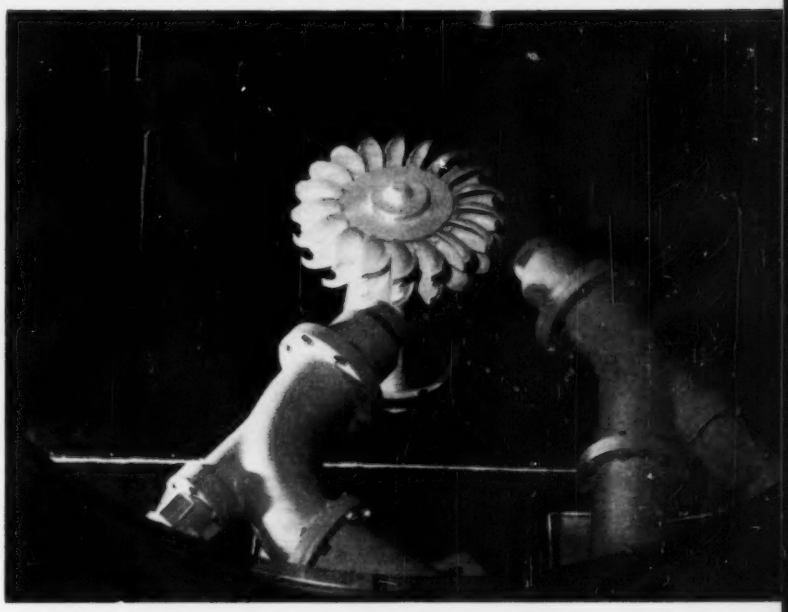
The top photograph is a view of the six dioramas showing some of the Industry's achievements in overseas countries. The next photograph is of another series of pictorial features showing how Britain gave the world steam power, electricity, and nuclear power. The centre picture is one of another series of dioramas, and illustrates a pumped storage scheme. It forms part of the entrance to the Chamber of Energy devoted to water power. On the right is a detail of one of the dioramas in the top picture, showing a main-line electrification project in Brazil where locomotives, multiple-unit trains, main and remotely controlled substations, overhead contact and transmission lines and structures were all supplied by British firms

The top picture on this and the facing page show two murals designed to symbolize the benefits which electricity brings to the most remote corners of the world. The backgrounds illustrate a nuclear power station and a hydro-electric installation respectively

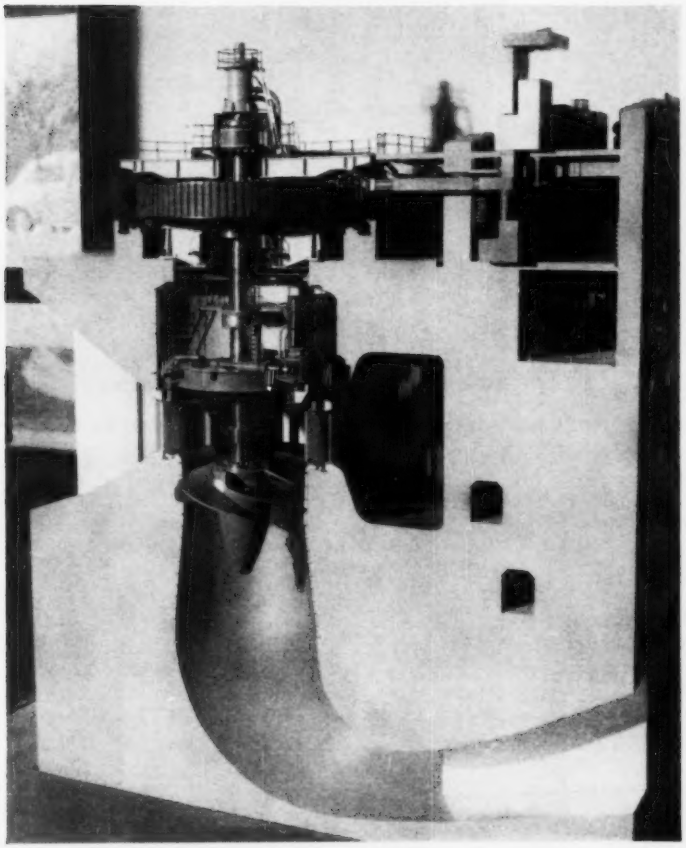
The centre picture on this page is a view from one end of the exhibit looking into the third Chamber of Energy. To the right of the Chamber is the railway signals bridge and beyond that the 275-kVA oil-filled circuit-breaker which is also featured on the front cover. The pictures below are two views inside the second Chamber of Energy, which is devoted to nuclear power. The four pictures, specially painted for the exhibit by Claude Buckle, give a striking impression of the four new nuclear power stations now under construction in Great Britain and scheduled for operation during 1960–62

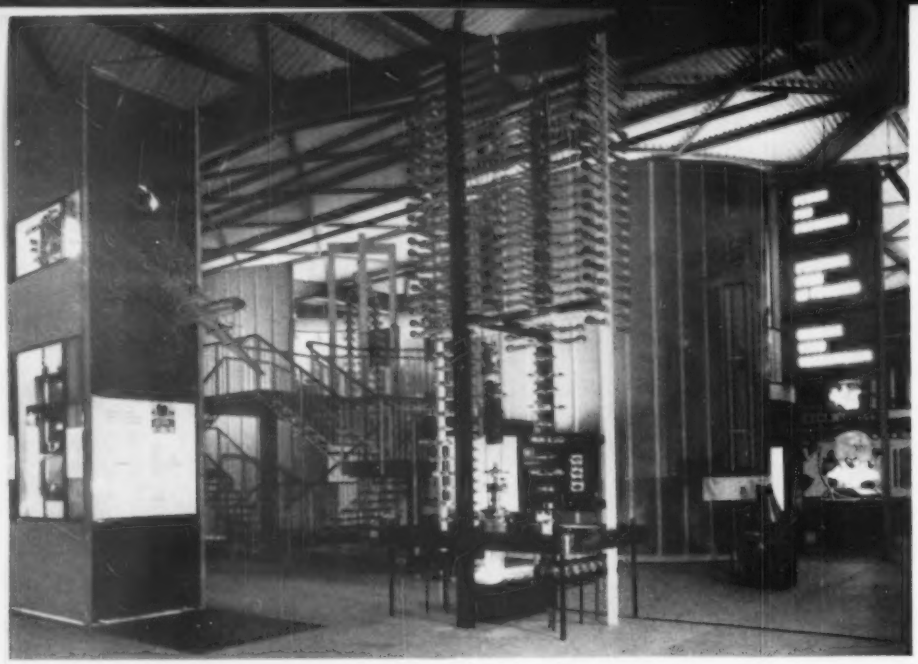




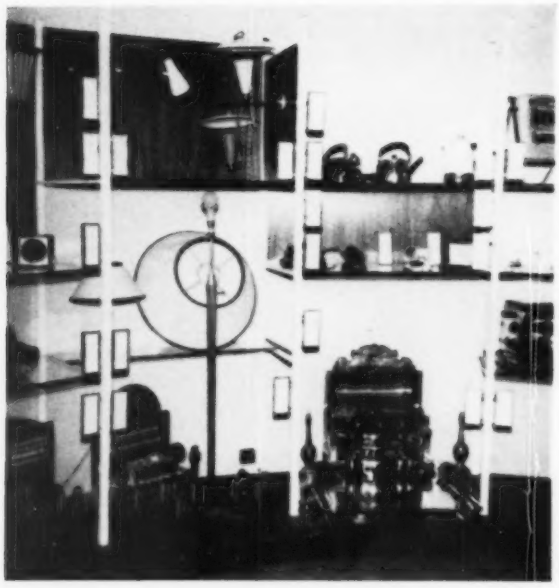


On the right is the working model, in a watertight tank, of an impulse turbine showing how the Pelton wheel is driven by the water jets. The lower left picture shows a working sectional model of a complete hydro-electric set as supplied by a British firm to the USA for the Priest Rapids hydro-electric scheme. The model shows how a propeller runner is used in practice. On the right is a close-up view of the full-sized propeller runner, which is slowly revolving above the heads of visitors to the Chamber of Energy devoted to water power





This general view of another corner of the exhibit shows the valve tower which comprises some 1500 British-made valves, and on the left the model of the new Bristol Britannia aircraft. In the centre of this picture is the staircase leading to the Domestic Section on the upper floor of this Chamber of Energy



Above is the top of the staircase, where a vista is obtained of part of the Domestic Section with exhibits of washing machines on the left and vacuum cleaners and similar equipment on the right. In the right foreground is the beginning of the cooker exhibit, and left, the top of the high voltage glass insulator. Centre right shows another corner of the Domestic Section with some of the smaller appliances including fires, kettles, etc. The bottom photograph shows part of the exhibit devoted to domestic electric cookers, with a member of the stand staff in the specially designed blue and white tailored uniform dress worn by all the ladies on duty in the British Electrical and Allied Industry's exhibit

The 1958 British Electrical Conference (organized by the British Electrical and Allied Manufacturers' Association) was staged in the 'Petit Auditorium' in the Brussels Exhibition on 16 and 17 May.

In his official opening at the first session, Sir Vincent de Ferranti, MC, President of the Conference, referred to its purpose in providing a common meeting-place for all those concerned with the design, manufacture, and utilization of electrical plant and equipment. He welcomed the large number of delegates from many parts of the world, and expressed the hope that they would all learn from one another and would find the Conference stimulating, interesting, and informative.

The first of the Conference papers was then presented, of which the following is the complete text.

Communication between Nations and between Peoples

Paper presented by

Sir Gordon Radley, KCB, CBE, PhD, MIEE

Director-General of the British Post Office

Introduction

'COMMUNICATION between Nations and between Peoples' is a subject that is very difficult to cover in the compass of an hour. In no branch of applied science—with the possible exception of the application of nuclear physics—has progress been more rapid during the past few decades. And there is a stimulating prospect of development during the remaining decades of the twentieth century far exceeding that which has already taken place.

It has been suggested that a time will come when most of us may possess, along with the other accessories of an electronic age, an instrument not much larger than a pocket-watch. It would have a screen on one side and ten buttons on the other. Using those buttons the owner would be able to call any other telephone subscriber the world over. The person answering would appear on the screen of the caller's instrument in three dimensions and in colour. The two would talk as if face to face.

Before dismissing that peep into the future as an idle fantasy, it is as well to remember that nearly all the facilities provided collectively by that pocket instrument can be provided separately now, although only by the use of expensive and bulky equipment. Telephony between a mobile station and most of the 110 million telephone stations existing in the world is technically possible; subscriber dialling to call any telephone within the national network is an objective in many countries. By 1970 three-quarters of all long-distance calls in the United Kingdom should be dialled by the callers, and plans for international subscriber dialling are being made by the appropriate International Consultative Committee. Eurovision, enabling viewers in many Western European countries to enjoy programmes of foreign origin, has become an accomplished fact, and there are about 200,000 television sets receiving programmes in colour in the United States. Stereoscopic vision, like stereophonic sound, only requires duplication of the communication channel.

The development of communications is at a most interesting stage. The basic ideas for providing more immediate and more intimate communication have been worked out in terms of broad functional designs. The speed with which our ideas can be realized in the form of cheap and compact apparatus will depend very largely on the development of new or improved components, in some cases of components that will effect an electrical or electrophysical transformation more neatly than at present.

My paper will take the form of a report on the effects, past and prospective, on world communications of four inventions. They are:

(i) the telephone,
(ii) the thermionic valve,
(iii) the cathode-ray tube, and
(iv) the transistor.

The Telephone

In a brief history of this kind I must leave out the telegraph, although it marked the start of electrical communication. My report stems from Dr Graham Bell's first transmission of the spoken word beyond the range of airborne sound. Neither the electromagnetic telephone receiver nor the carbon microphone has changed fundamentally since their introduction. The efficiency of both has been greatly increased as a result of unceasing research and experiment, and the latest British designs are good examples of the modern telephone set. Some are notable because all the internal components can be mounted on a base-plate with interconnexion by means of printed circuits. Within the United Kingdom a new telephone set is planned to meet the international requirements for transmission when connected to a subscriber's line with a loop resistance of 1000 ohms. The greater efficiency of the instrument can mean worthwhile reductions in the size of the copper wires required in the distribution cables and in the amount of space which a cable providing a given number of connexions occupies in an underground conduit. Distribution by underground cables is

almost universal in all urban areas, and the civil engineering costs involved in placing cables underground have been rising rapidly. They have followed the upward trend of labour costs all over the world. Therefore, any technical development which can reduce the need for civil engineering work, or postpone it, is particularly useful.

The problem of the rising cost of connecting a telephone subscriber to his local exchange will remain while each subscriber requires a separate pair of wires, or a share in a pair of wires, for this connexion. Any cheap method of providing multiple voice-paths over wires in local cables, so that each additional subscriber does not mean an additional pair of wires, would hold great promise for the future. A complete change of practice and the adoption, in simplified form, of techniques hitherto applied only to long-distance transmission would be necessary. A cheap solution may be brought nearer with the use of equipment employing transistors. In the meantime the outstationing of what are effectively parts of the telephone exchange, such as line connectors and ultimately electronic switching units, may help to keep down the costs of distribution.

Fig 1 (left). *The latest British telephone set is a notable example of modern design*

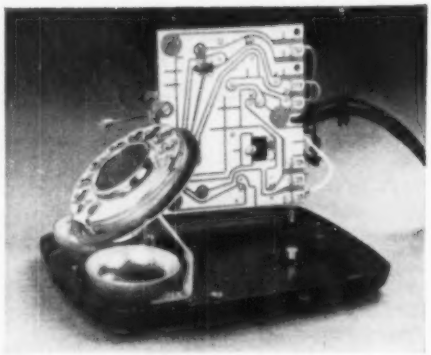


Fig 2 (right). *A typical British printed circuit chassis*

The Thermionic Valve

The invention of the thermionic valve and the subsequent development of the valve repeater converted telephony from a local to an international means of communication. In combination with the coaxial cable, repeaters capable of handling a wide band of frequencies have made long-distance telephone circuits comparatively cheap. Cables transmitting up to some 1000 speech channels within a single coaxial tube provide large groups of circuits between the main centres of population in many countries. In the United Kingdom the same line plant with appropriate repeaters is used to provide television links rented to the broadcasting authorities. As traffic demands, the spacing between repeater stations on some main routes in the United Kingdom will be reduced from 6 to 3 miles (9·7 to 4·8 km). The traffic capacity will thereby be increased and each tube will provide a path for 1000 telephone channels plus a 5-Mc/s television channel. To meet both these requirements requires the use of valves of a performance better than anything in current use, but we have already achieved a measure of success in this direction.

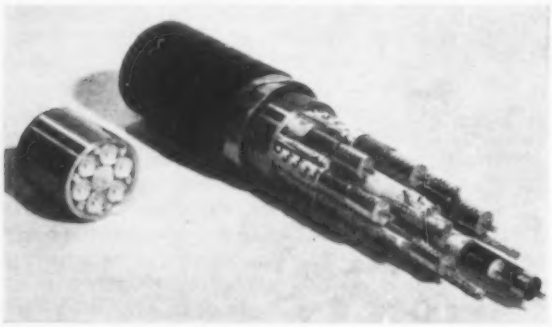


Fig 3. Showing the construction of a multi-channel coaxial telephone cable

The coaxial cable system is being augmented in some national networks by radio-relay systems operating on centimetric wavelengths (micro-wave) and capable of providing several independent broad-band transmissions. Each of these transmissions will carry several hundred telephone channels or a television channel. In these systems the signals are beamed over a line-of-sight path, amplified, and retransmitted. A micro-wave radio-relay system, provided for television transmission in the United Kingdom in 1952, was the first in Europe to make use of the travelling-wave tube as an amplifier.

Long-distance communication networks are developing in many countries on the basis of an integration of radio and physical links. In the United States these links take the form of micro-wave systems and coaxial cables. In some countries where the communication requirements are less—in Africa for example—they consist of VHF radio relay systems and open-wire carrier.

The United Kingdom has traditionally been to the fore in the development of radio communications. Marconi brought his invention to England. Spark transmitters were used for the early experiments and for the early telegraph services. High-power valve transmitters came next and the British Post Office was a pioneer in the use of them for long-distance services. They made radio telephony, and ultimately broadcasting, possible.

The American Telephone and Telegraph Company and the British Post Office were together responsible for the first public radio-telephone service between Europe and the United States. The service was opened over thirty years ago using high-power long-wave single side-band transmitters. Short-wave (high-frequency) transmitters with directional aerial arrays followed quickly and many of these were installed at Rugby, working to stations all over the world. Largely as a result, the United Kingdom

became a centre for world-wide telephony. Many conversations between the widely dispersed Commonwealth countries and the rest of the world are still switched in London. For example, a telephone connexion from Beirut in the Lebanon to Sydney in Australia would be via London.

Radio transmissions must continue to play an important part in the longer distance point-to-point interconnexions for many years to come and will continue to provide the only links to mobile stations, *e.g.* ships and aircraft. In order to provide for services terminating in, or switched through, the United Kingdom, a new radio

Fig 4. Radio-relay stations of the future, operating on centimetric wavelengths, will look like this. Micro-wave links will replace multiple aerial arrays

transmitting station has been built alongside the old one at Rugby. It was opened in 1955. The new station is probably the biggest ever to be built as a single project. It is certainly well in advance of any other in technique, and houses 28 high-frequency transmitters capable of providing independent transmissions on the two side-bands. The site will accommodate over 70 aerials, mainly of the rhombic type, arranged for communication to most main centres throughout the world. The station has been designed to reduce operating costs. All the transmitters are operated and monitored from a central control from which any transmitter can be brought into service on any one of the prescribed frequencies, connected to any aerial, and its performance monitored.

The particular susceptibility of the North Atlantic route to ionospheric disturbances, together with the inadequate number of radio frequencies to provide circuits, had long emphasized the limitations of radio-telephony for communications between Europe and North America. The long-life thermionic valve made inter-continental telephony by cable possible. An agreement to lay a cable was announced in December 1953; it was between the American Telephone and Telegraph Company, the Canadian Overseas Telecommunication Corporation, and the British Post Office. In order that the very large capital investment required should be profitable, revenue had to be earned on traffic carried by a large number of circuits. A long submarine telephone cable, particularly one transmitting a wide band of frequencies in order to provide many telephone channels, poses problems additional to the many that were associated with the first transatlantic telegraph cable. This operated at a speed of only three words a minute, corresponding to a top frequency of 1·5 cycles per second. The inductively-loaded telegraph cables constructed in the 1920s handled traffic at speeds corresponding to frequencies up to 100 c/s. If one of the new transatlantic telephone cables had to transmit signals at no frequency higher than this, its overall attenuation would be about 200 db; at the top frequency at which it is actually used the overall attenuation is 3200 db—a power ratio of 10^{320}. Herein lies the greatest difference between the new transatlantic telephone cable and the world network of telegraph cables which have been installed during the past ninety years.

It is only the amplification of the signals at intervals along the route that makes telephony possible over long submarine cables. A device to do this—the underwater counterpart of the repeater station on land—was constructed in the Research Laboratories of the British Post Office in 1942. It was used in the Irish Sea. In 1946 a coaxial telephone cable was laid between Lowestoft and Borkum, a distance of 196 nautical miles (314 km), which contained one repeater in comparatively shallow water. These two early applications were the first uses of submerged repeaters for telephone traffic anywhere.

The next stage was to develop repeaters for operation in tandem. British experience of the frequent damage to cables in the North Sea and the Channel by fishing trawlers had led to a firm preference for making every cable self-contained. The Post Office therefore took as its target both-way speech transmission for a super-group of 60 circuits over a single cable. Separate frequency bands have to be used for the two directions, and the system designed originally for use in cables which already existed in the North Sea transmits 60 speech channels in the 'go' direction in the frequency band 24 to 264 kc/s; the corresponding channels in the 'return' direction are transmitted in the frequency band 312 to 552 kc/s. Low- and high-pass filters are necessary to separate 'go' and

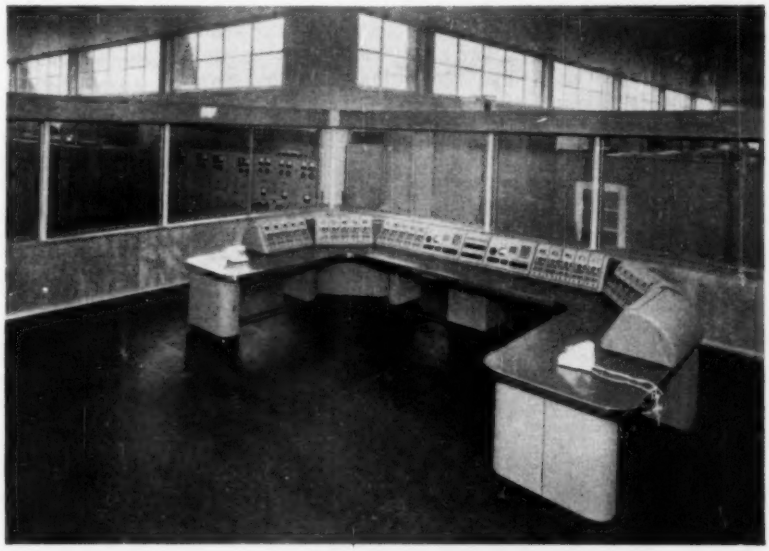


Fig 5. The central control position at Rugby 'B', giving remote control of the 28 high-frequency transmitters

'return' channels in each repeater. The outputs from the filters are arranged to feed into a common amplifier.

The use of a single both-way cable, instead of two separate one-way cables, poses additional problems. First, because of the higher maximum frequency that has to be transmitted, both-way cables require more repeaters than would be required for voice channels in one direction only. Second, the electrical components necessary to make up the high- and low-pass directional filters in the repeaters are somewhat bulky. There was, however, ample room for these filters in the comparatively large rigid steel housings used for the early British repeaters. On routes where a single both-way cable will suffice for the traffic it is, however, much cheaper than two one-way cables.

Normal commercial valves were used for the early British repeaters. They were of a type known to have good life characteristics. Three failures have occurred, but in the shallow waters of the North Sea it is a comparatively easy operation to replace a repeater. On the other hand, replacement of a repeater in deep water may be a most hazardous and expensive operation, particularly if it has to take place in winter. Faced with the probability of valves being required for use in ocean cables, the British Post Office Research Laboratories gave attention to the design of valves meeting the specific requirements of submerged repeater usage. The objective was a high-transconductance valve, capable of wide frequency coverage but only requiring a low anode voltage. Expectation of very long life was essential. It was also necessary that performance should not change appreciably during life. As a result of intensive laboratory research on the electrochemical processes occurring during the life of a valve, a considerable measure of success has been achieved. Valves are now available in the United Kingdom meeting these exacting requirements.

A telephone cable containing 7 repeaters in housings of an improved type was laid in 1954 between Scotland and Norway. The cable is about 300 nautical miles (560 km) long and was, at the time, the longest submarine telephone cable in the world.

This Scandinavian cable introduced a new technique in repeater circuit design. The amplifier in each repeater had two forward paths in parallel with a single feed-back path. The duplication of valves and other components provided by the two forward paths was so arranged that

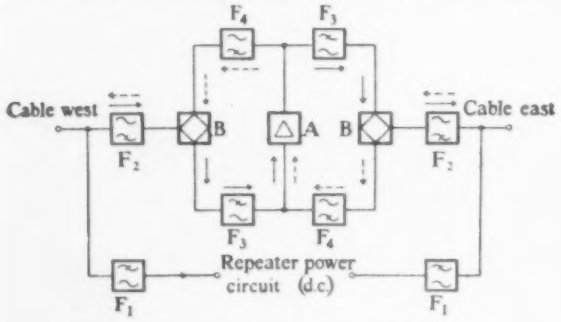


Fig 6.—Schematic of both-way repeater.

A. Amplifier.
B. Balanced bridge.
F_1, F_2. Low- and high-pass power filters.
F_3, F_4. Low- and high-pass directional filters.
→ West-east channels, l.f. group.
← East-west channels, h.f. group.

any valve or other component could fail in practically any way without affecting the overall performance of the repeater. The arrangement enables modern valves and other components without a long life history behind them to be used with greater confidence.

At the end of 1954 when manufacture of the transatlantic cable was commenced, there were 41 submerged repeaters operating in telephone cables in European

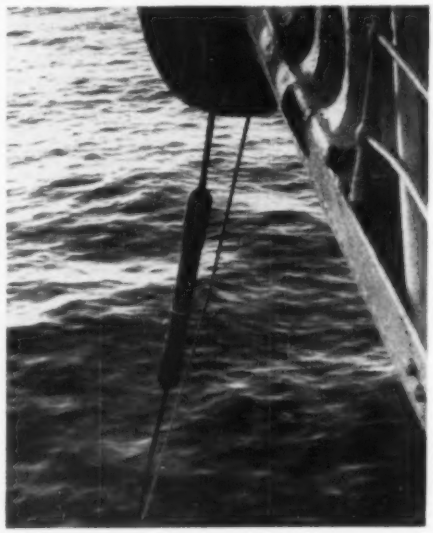


Fig 7. Lowering overboard from the cable-laying ship a rigid deep-sea repeater

waters. All these cables and repeaters had been constructed in the United Kingdom and laid by British ships. The only other submarine telephone system anywhere in the world containing repeaters was that consisting of a pair of cables connecting Key West in the United States with Havana. These cables are approximately 120 nautical miles (221 km) long and lie in water nearly a mile deep. Each cable contains three repeaters and provides one-way transmission for 24 voice channels. This system represented the culmination of many years of work in the American Bell Telephone Laboratories on the development of coaxial cable and repeaters suitable for a transatlantic crossing.

It here becomes necessary to say something about the process of laying cable at sea. The basic machinery now in use on ships is a drum about which the cable is looped as it passes from the cable tanks to the sea. The drum is braked to prevent the cable from slipping too rapidly into the water; it is driven when cable is being picked up.

The British repeater housings used for the cable between Scotland and Norway were designed to withstand the water pressure at depths of more than two miles below the surface. Each housing was a rigid steel case, about 10 inches (25 cm) in external diameter, nearly 9 feet (2·7 m) long, cigar-shaped and in line with the cable. These rigid repeater housings will not, of course, follow the cable around the cable drum but, with manual handling of the repeater past the machinery, it has proved quite practicable to lay large, rigid housings at intervals of about 16 nautical miles (29·8 km) in comparatively shallow water. The ship must be stopped and the assist-

ance of practically all the deck crew is required. A risk of damage to the cable arises if the operation is undertaken in deep water because the stored torsional forces in the steel armouring wires tend to throw turns in the cable. The turns may be subsequently pulled into kinks, so damaging the cable structure. This is likely to happen if the ship stops with a long length of cable suspended below it.

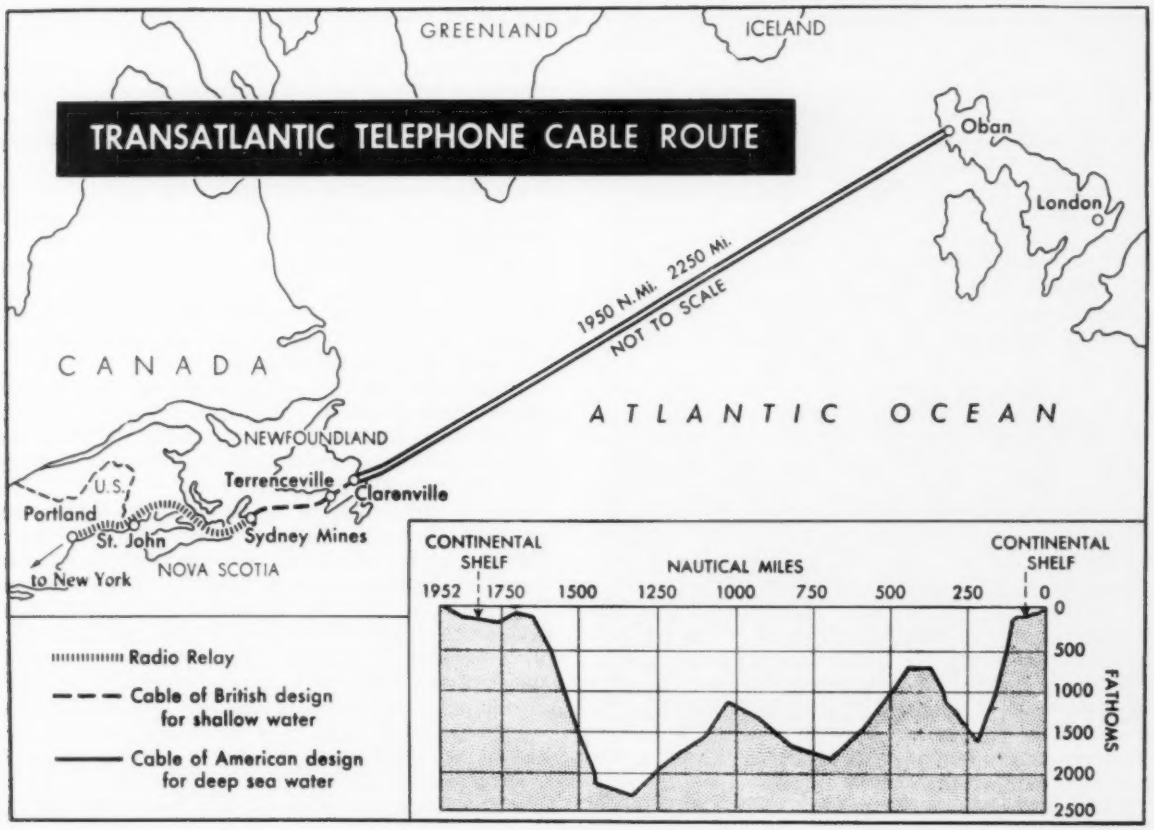
The desirability of a structure which would behave as nearly as possible like a corresponding length of cable led engineers in the Bell Telephone Laboratories to the design of a flexible repeater housing. This housing will go round the normal cable machinery without damage to itself and can be paid out without stopping the ship. It consists of two layers of butt-jointed steel rings which support an envelope in the form of a long copper tube. The housing, and the seals by way of which the inner conductor is admitted to the central compartment, will withstand a water pressure of three or four tons/sq in (6 kg/sq mm). The internal diameter of the central compartment is not much more than 1 inch (2·5 cm); the compartment is about 10 feet (3 m) long. It contains three valves and about 60 other electronic components. This housing was first used for the Key West–Havana cables.

The choice of this form of repeater housing for the main section of the first transatlantic cable was determined by the fact that proved reliability and the avoidance of unnecessary risks in handling cable and repeaters were essential in the pioneering and costly venture to be undertaken. The small amount of space available in this flexible housing for the electrical components, the knowledge that every additional component would add a potential risk of failure, and the fact that simplicity of design and reliability usually go together, dictated the choice of repeaters which would only amplify signals passing in one direction. There are, therefore, twin cables between Scotland and Newfoundland; one transmits speech from East to West, the other in the reverse direction. Each cable contains 51 repeaters. Each repeater compensates for the loss in the 38 miles (61 km.) of cable preceding it, increasing the power of the signals roughly one million times. Together the two cables provide 36 telephone circuits, each circuit occupying a 4 kc/s channel in each cable. The highest frequency transmitted is 164 kc/s.

Newfoundland is joined to Nova Scotia by a single both-way cable providing 60 telephone circuits. The cable lies in comparatively shallow water. It contains 16 repeaters. The core design and diameter is the same as that used for the main transatlantic crossing, with armouring appropriate to the depth of water in which the cable lies. Because of the higher frequencies that have to be transmitted to meet the requirements of a greater number of circuits and both-way transmission, the 16 repeaters are only 20 miles (32 km) apart.

Practically all the cable required for the first transatlantic system was manufactured in the United Kingdom. American-made repeaters for the main crossing were flown to the United Kingdom and joined into the cable before it was loaded on to the cable ship *Monarch*. The repeaters for Newfoundland–Nova Scotia were of generally similar design to those first used for the Norwegian cable and were made in the United Kingdom.

The key to the success of this project was the possession by the Post Office of the cable ship *Monarch*. *Monarch* is the only cable-laying ship afloat capable of



laying a cable across the deep section of the North Atlantic in one operation. This was desirable in order to avoid the risk of kinking if the laying operation had to be stopped in order to make a joint with deep water under the ship. The whole operation, including the laying of the cable from Newfoundland to Nova Scotia, took two summers, during the course of which at least one repeater had to be laid in a gale which would have made any cable-laying operation difficult.

Installation of the cable system meant the placing of 400 valves and about 7000 other components on the ocean-bed. Between Newfoundland and Scotland, failure of any valve would mean that telephone conversation over the cable would cease. So far none has failed.

The cable was opened for traffic in September 1956. During the first twelve months very nearly 300,000 telephone calls were connected between the United Kingdom and North America. In addition the cable carried about 130,000 calls between the United States and Continental countries over seven circuits leased to foreign administrations, including one circuit terminating at Brussels. At the end of last year telephone traffic between the United Kingdom and the United States was twice what it was before we had the cable; traffic to Canada had increased three times. Cable capacity, especially to Canada, has become a limiting factor at peak traffic periods. The number of circuits to Canada has recently been doubled at peak traffic periods by the use of specially designed narrow bandwidth channels. Traffic is still increasing.

At present the speech channels are normally spaced 4 kc/s apart. The range of speech frequencies effectively transmitted extends from 300 to 3400 c/s, thus meeting the international requirements for long-distance telephone circuits. The attenuation characteristics are shown in dotted lines on Fig 8. The British Post Office, working in conjunction with a manufacturer, has developed equipment which will give practically the same quality of speech transmission with channels spaced only 3 kc/s apart. The result, in terms of the attenuation characteristic of the speech channel, is shown in full lines on Fig 8. It represents a notable achievement in the design and construction of channel filter equipment, wasting less than 200 c/s per channel in place of the 900 c/s lost with the normal channel spacing. Use of 3 kc/s channels will, of course, increase the traffic capacity of the cable by 33⅓ per cent, and it is likely that all new cables will be planned on the basis of 3 kc/s channels.

Another engineering development being undertaken by the Bell Telephone Laboratories may, if successful, add further to the capacity of transoceanic telephone cables. This it will do by taking advantage of the intervals when people are listening. The speech channels left temporarily unused will be assigned to other conversations, but when a listener starts to talk he will instantly have the use of a channel which is temporarily idle.

In 1957 the American Telephone and Telegraph Company completed twin cables from the American Pacific seaboard to Hawaii, part way across the Pacific Ocean. This twin-cable system repeats the design of the first transatlantic cables between Newfoundland and Scotland. The American Company has also announced its intention,

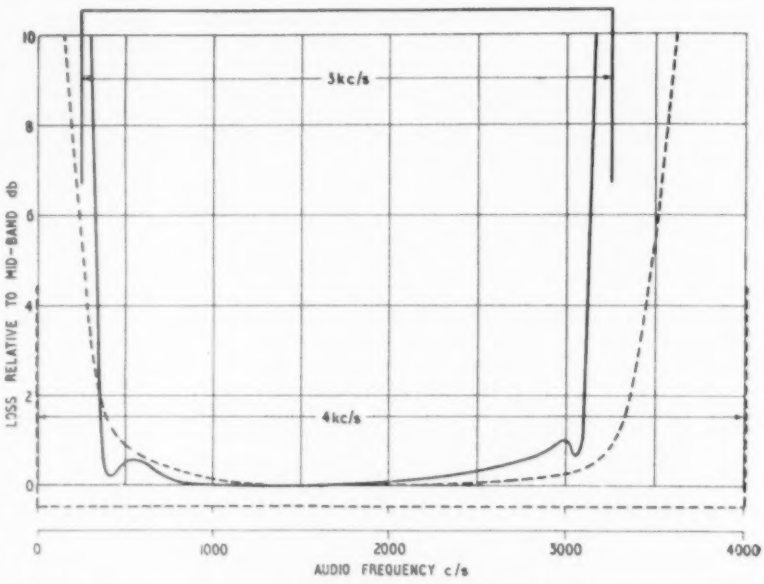


Fig 8. Attenuation characteristics of speech channels with 4 kc/s separation (now in use), and 3 kc/s separation (new development)

with the French and Federal German Administrations, to lay a second transatlantic system in 1959. This, again, will be similar to the system completed in 1956, and follow the same route except that it will land in France instead of in Scotland.

A cable is proposed for 1961 which will represent a distinct technical advance from these early transoceanic submarine cable systems. The cable will be between the United Kingdom and Canada and provide for the growth in Canadian communications. The project will be undertaken by Cable and Wireless and the Canadian Overseas Telecommunication Corporation, with technical assistance from the British Post Office.

There will be a single cable providing 'go' and 'return' speech channels for 60 telephone circuits (80 if 3 kc/s channels are used). To provide these facilities over one cable instead of two will require about 90 repeaters—one every 25 nautical miles (46 km).

Because the repeaters for the new Canadian cable must amplify signals passing in both directions the repeater housings will have to accommodate directional filters. This means that they must be fairly large, and therefore rigid. The flexible type of housing is not only inadequate for both-way repeaters but provides no room for duplication of circuit elements or components in any repeater. New types of laying machines to handle rigid repeater housings as part of a continuous cable-laying operation have been tried in the laboratory and at sea. The method adopted for the Canadian cable will be to use a loop of dummy cable which will pass round a series of coupled V-sheaves replacing the

cable drum. The repeater will be free to by-pass the machinery.

Repeaters in rigid steel housings were laid experimentally by the new method during February 1958. The trials took place in water $2\frac{3}{4}$ miles (4420 m) deep, some of them in rough weather. No difficulties were experienced with either the repeaters themselves or with the cable because of their inclusion. A new type of deep-sea cable was used.

For the last few years the Post Office has been experimenting with a new type of construction in which the strength member is placed at the centre of the inner conductor. High-tensile steel wires can be used and in stranded form can be designed to have no tendency to twist under tension. Since protection is unnecessary in deep water, where almost perfect quiet reigns, no outer steel armouring is necessary. Armouring must be introduced where the water becomes shallow. But it is possible that armoured deep-sea telephone cable will rapidly become obsolescent.

The Cathode-Ray Tube

From the transmission of sound we pass to that of vision.

Television would have remained in a very elementary stage had not electronic methods of picture scanning and reproduction been devised. By 1935 a stage had been reached in the United Kingdom when Shoenberg was able to suggest a high-definition system of 405 lines with 50 picture frames per second (interlaced). Transmissions using this system were commenced by the BBC in November 1936, and Britain takes pride that this was the first regular system of high-definition television broadcasting anywhere. By the end of 1957, coverage of the BBC television service exceeded 98 per cent of the population of the United Kingdom.

Since 1936 there have been continuous improvements in electronic cameras using cathode-ray scanning of an electrically charged screen, and in the cathode-ray tube as a viewing service. As a result of extensive electron-optical development work by Gabor in the United Kingdom, a flat thin television tube for monochrome or colour now appears feasible. Its thickness is only about one quarter of its screen diagonal. Higher definition systems have been introduced for public entertainment. Quite apart from these, closed circuit television has extended our ability to see at a distance for a variety of purposes, from traffic control to investigations at the bottom of the sea and the inspection of manufacturing processes.

The introduction of colour has appeared imminent for several years, and broadcasts in colour have been regularly made in the United States since 1953. But although great technical ingenuity has been exercised in the development of colour systems, and field trials are being carried out in the United Kingdom and elsewhere, the large-scale introduction of regular colour services appears to be some way off. To a great extent colour development must be influenced by the existence of some 64 million receivers capable of receiving in monochrome only. A fully compatible system is essential. This means that colour transmissions must be receivable in black and white on normal monochrome television receivers, and conversely that a monochrome transmission should be receivable in black and white on a colour receiver. Both these results should be obtainable without undue degradation of the picture. And finally they should be achieved without any very large increase in the frequency bandwidth required for the colour transmission.

The American National Television Standards Committee (NTSC) system was designed to meet these requirements. In it the luminance and chrominance information is transmitted separately, the chrominance signal being located within the frequency band normally occupied for the transmission of the black and white picture. In the receiver the colour effect results from the simultaneous viewing of red, green, and blue pictures, using a three-gun cathode-ray tube with an in-built shadow mask. Many engineers feel that a basically simpler reproducing device is required before colour television can become cheap and popular.

The Transistor

The invention of the transistor was announced on 30 June 1948. The transistor illustrates in a beautiful way the manner in which developments in widely separated branches of science can come together, and all play an essential part in producing a new facility. Much of the basic research in the realm of solid state physics leading up to the invention was undertaken by Bardeen and Brittain in the Bell Telephone Laboratories, but the contributions made in the more theoretical field by such workers as Mott must not be overlooked. The announcement of this device seemed at once to open up the possibility of new developments in telecommunications. I propose to mention three.

The first is in the development of carrier-frequency telephone transmission systems suitable for short distances and lightly loaded routes. The transistor amplifier requires only a small amount of power which can be taken

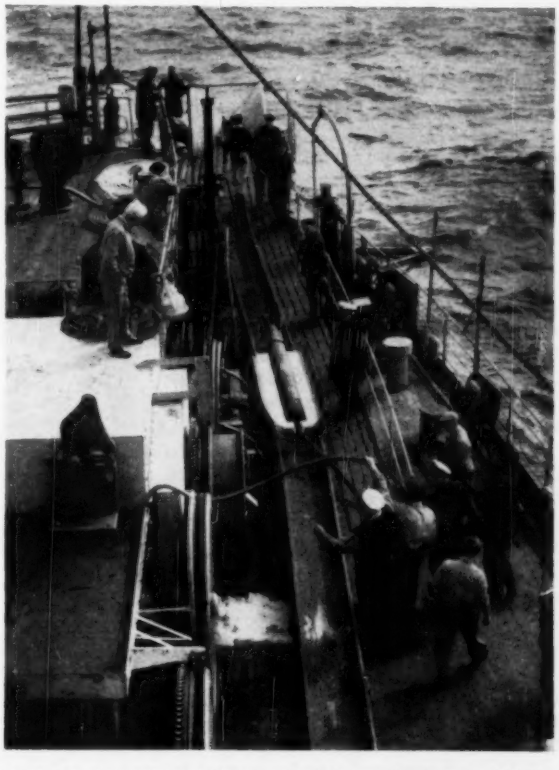


Fig 9. On board HMTS Monarch *during cable-laying trials last February. One of the large rigid both-way repeaters for the Canadian cable is being by-passed round the cable drum*

from a low-voltage source, and with care in the manufacturing process the life of a transistor should be long. These are great advantages. So, of course, is the very small size of the transistor itself and consequently of the apparatus which uses it. There is the possibility of reliable, cheap, and small transistor amplifiers being installed on poles and in manholes, and a transistorized rural carrier system of British design and manufacture is now in fact available. This carrier-frequency equipment is operated from batteries and this enables the benefits of multi-

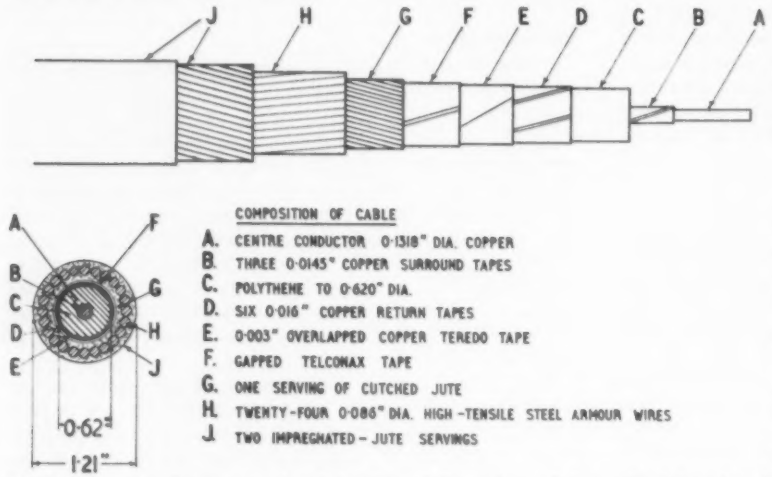


Fig 10. Showing the constructional details and dimensions of the earlier (above) *and the new type* (below) *submarine cable used by the British Post Office. In the latter, the strength member is placed at the centre of the inner conductor*

channel working to be extended to areas where no electricity mains are available.

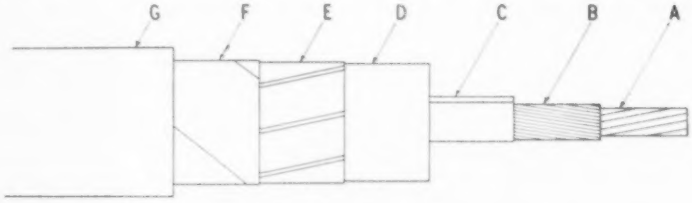
The second possibility is the use of transistor amplifiers in trans-ocean telephone cables, where the supply of power to valve amplifiers often constitutes a problem. In the case of the first trans-atlantic telephone cable system, dc power is fed to the 51 repeaters in each of the cables between Newfoundland and Scotland by constant current generators at the two ends. The total driving voltage required is 4000; with transistor amplifiers the voltage requirements would be much less.

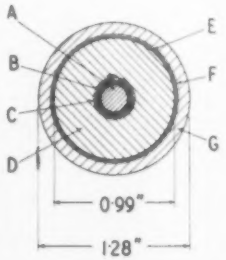
Much work has yet to be done to mature the transistor art to the level of the thermionic valve. Positive evidence of long-term consistency of characteristics and long trouble-free life is required before they are adopted for underwater working. The art is, however, a progressive one and transistor amplifiers suitable for submarine cables may be developed.

If transistor amplifiers with low power requirements can be embodied in small repeaters connected into a cable at relatively short intervals, the widening of the transmission band could provide for more speech channels with accompanying decrease in cost per circuit. During the first ninety years of electrical communication across the North Atlantic, the highest frequency which could be transmitted on a cable channel increased from 1½ c/s to 100 c/s. Within the last five years it has increased to 164,000 c/s. With the opening of the Canadian cable in 1961 it will become over half a million c/s. One-way transmission of television of reasonable definition and quality should be achieved within a frequency bandwidth of not more than 2 Mc/s. Television cables between Europe and North America appear quite a technical possibility within the next ten years.

The third application of the transistor is in the switching of telephone circuits. Eighty per cent of the world's telephones now depend on automatic switching for local calls. In most countries the operators who handle the remainder are rapidly being replaced by machines.

The development of automatic switching in the United Kingdom has been based on the use of the step-by-step system and two-motion mechanical switches. The system and equipment are simple in principle, easy to maintain compared with some other electro-mechanical systems, and versatile in application. Embodied into a director network, step-by-step equipment has provided for the requirements of very large multi-office areas, such as London and Manchester. It has provided also the simpler switching facilities required in a small rural exchange. British-made step-by-step equipment is giving satisfactory service all over the world under





COMPOSITION OF CABLE
A. 1+9+9 DIE-FORMED STEEL STRAND 0·236" DIA. L.H. LAY
B. 24×0·032" DIA. STEEL WIRES R.H. LAY
C. LONGITUDINAL COPPER TAPE WITH BOX SEAM. 0·010" THICK
D. Pe INSULATION (GRADE 0·3 PLUS 5% BUTYL RUBBER) TO 0·99" DIA.
E. 6 ALUMINIUM TAPES 0·505"×0·015" L.H. LAY
F. TWO 0·010" COTTON TAPES WITH CORROSION INHIBITOR OVERLAPPED
G. Pe SHEATH (GRADE 0·3 PLUS BUTYL RUBBER) 0·110" THICK

widely varying conditions of service. Switches and apparatus have been improved in mechanical design during recent years, and the installation of modern step-by-step equipment should remain a satisfactory way of meeting telephone switching requirements for many years to come. Taking a slightly longer view, however, it appears that developments in the electronic

field should make it unnecessary to rely on the positioning of mechanical switches as the only practical way of connecting two telephone circuits together. Use of electro-mechanical switches and relays to store dialled information, for the later control of a complicated switching operation, seems likely to be even less necessary in the future because of the great amount of progress that has been made in the development and use of electronic memory devices in computers and control systems generally. Cathode-ray tubes with thousands of tiny capacitors deposited on the screen, assemblies of cheap mass-produced ferrite cores, delay lines, and the magnetic drum are four different forms of electronic memory that have been used for storing large amounts of information. Magnetic storage has made considerable progress during the past year or two. The art of storing information electronically has now reached a stage when all such requirements of a telephone exchange could be easily met. The problem of connecting two speech circuits together is a more difficult one. There are three possible ways of doing this. The first is by using gas diodes, or some other device for interconnecting the speech circuits in a space multiplex. The second arranges the circuits to which connexion can be offered in a frequency-division multiplex. The third does the same in a time-division multiplex. The system which has reached a late stage of development in the United Kingdom uses time-division multiplex for interconnecting the speech circuits and for control.

Many telecommunication laboratories throughout the world are pressing on with the development of electronic switching systems which, sooner or later, will render the present electro-mechanical systems obsolescent. In the United Kingdom, research and development resources have been pooled for this purpose by the Post Office and the telephone industry, as represented by the five principal switching equipment manufacturers in it. A basic design has been chosen after consideration of the experimental work done by all. Development and construction of the functional units is now being shared between the parties with the target of having an all-electronic exchange constructed and ready for bringing into public service at Highgate Woods in North London in 1960.

Ultimately the production cost of an electronic exchange is likely to be less than that of the corresponding mechanical equipment. Smaller and cheaper buildings will suffice to house the equipment, and incidental savings in capital expenditure on local cables will be possible if the network can be adapted to the system. Maintenance costs should be appreciably less.

All this, however, will depend on the extensive use of transistors within the exchange circuits. Valves could be used for the particular functions for which transistors are envisaged, but the power and space requirements of an all-electronic exchange, engineered exclusively with valves, would make it impossible to realize the expected savings under these heads.

Conclusion

It is perhaps appropriate that I should conclude with this reference to progress in the art of switching telephone circuits. It will become easier to connect two people together wherever they may be. The other developments which I have been able to describe in this paper leave us far short of that peep into the future which I gave you at its beginning. But research is vigorously in progress in many laboratories. It has been said that its objective is 'to enable anyone, anywhere, to pick up a telephone and to speak to anyone else, anywhere else, quickly, clearly and at reasonable cost'.

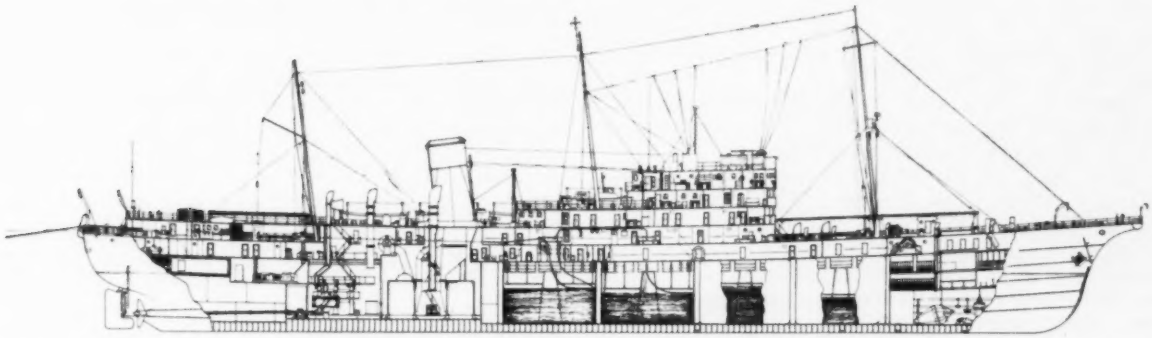


Fig 11. A sectional drawing of the cable ship HMTS Monarch *belonging to the British Post Office.* Monarch *is the only cable ship afloat capable of laying a cable in one operation across the deep section of the North Atlantic*

Sir Gordon Radley's paper was followed by the showing of a film 'The Transatlantic Telephone Cable', illustrating the work and techniques described in the paper.

That concluded the first session of the Conference, and after luncheon in the Alouette Restaurant in the Canada Pavilion (by permission of the Commissioner General for Canada), the members were invited to visit the British Section in the Exhibition and to inspect the British Government and the British Industry Pavilions. The joint hosts at the luncheon were Sir Vincent de Ferranti (President of the Conference), Sir John Balfour (UK Commissioner General), and Sir Hugh Beaver (President of the Federation of British Industries).

The second session of the Conference was held in the afternoon of Saturday 17 May, the morning having been left free to allow delegates to visit the Exhibition or to join a conducted tour of Brussels which had been arranged as part of the Conference amenities.

The following is the complete text of the second Conference paper.

Nuclear Energy—the Power of the Future

Paper presented by

Sir John Cockcroft, OM, KCB, CBE, FRS

Member for Scientific Research, United Kingdom Atomic Energy Authority

BRITAIN has by now had two years of practical operating experience on the world's first full-scale nuclear power station. The Calder Hall nuclear power station obtains the heat equivalent of 180 MW from each of two graphite moderated CO_2 cooled reactors. Each reactor contains 130 tons of uranium metal bars sheathed in magnox cans and these fuel elements operate at a surface temperature of 408 deg C. The CO_2 leaves the reactor at a temperature of 336 deg C and passes through one of four heat exchangers where steam is raised at a temperature of 313 deg C and a pressure of 210 lb sq in (14·76 kg/cm²). The steam is fed to turbo-generators which generate a gross output of 90 MW, of which 15 MW is used internally to drive CO_2 circulators and other auxiliaries, so the net output of the station is 75 MW.

Experience of two years of operation has shown that the design has been conservative and that a ten per cent greater output can be comfortably achieved.

Calder Hall operates as a base load station for the electricity authority and is subject to their central load control. The operational load factor has been high. The second reactor has achieved a load factor higher than the normal load factor of conventional power stations and is shut down mainly for planned maintenance operations on conventional components at weekends.

In spite of this, flexibility of operation is an important characteristic. The power levels can be increased at the rate of 10 MW thermal per minute, the limit being set by thermal stresses. The usual operational rates are limited to 5 MW per minute, so that it is possible to increase load from 30 MW to 180 MW in half an hour. This is just as fast as a conventional power station.

One of the most important points in the performance of a nuclear power station is the behaviour of the fuel elements. We had previously operated uranium fuel elements in the Windscale reactor at surface temperatures of 370 deg C. The Calder Hall fuel elements are operated with surface temperatures about 40 deg C higher and the heat ratings of the fuel elements were increased substantially. During the construction of Calder Hall, Dr Cottrell discovered at Harwell that irradiation of uranium can produce creep at 100 times lower stresses than are normally required. In Calder Hall, six fuel elements are stacked vertically one above the other in each channel, so the bottom fuel elements are heavily loaded, and we found that the additional radiation-induced creep caused the lower elements to bow like struts. The magnitude of the effect agrees well with the Harwell experiments. The bowing has been prevented by fitting additional central supports for the fuel elements. In future designs the weight of each fuel element will be taken by the graphite.

Apart from this experience, the behaviour of the fuel element has been good. During fifteen months of operation of the first charge of No 1 reactor at Calder Hall, only three fuel elements out of 10,000 developed slight leaks in the magnox sheath. This resulted in a slow in-leakage of carbon dioxide leading to slow oxidation of the uranium metal and a corresponding small out-leakage of fission products into the circulating gas. The leakage is detected by electronic devices which periodically sniff a sample of gas from each channel and any radioactive content is plotted on pen recorders. The radioactivity increases only slowly with time—a typical chart being shown in Fig 1. So there is no urgency to change the

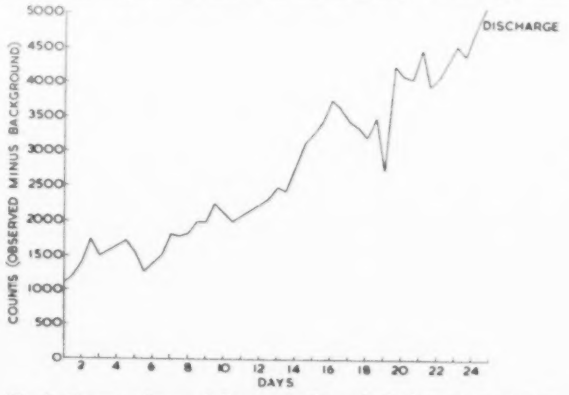


Fig 1. Counts observed from a leaking fuel element in Calder Hall showing increase in radioactivity

defective fuel elements and it can be done at the next regular maintenance period. The faulty fuel elements are stacked under water because they are radioactive and are then examined by radiography. The outline of the uranium fuel element is then clearly seen and it is usually possible to see a slight bulge caused by the oxidation. The fine crack responsible for the fault is difficult to see. It appears that the very slow expansion of the uranium fuel due to irradiation can strain the magnox can sufficiently to cause a few such faults to develop. We are changing the grain size to increase the ductility of the magnox and this ought to cure this small trouble.

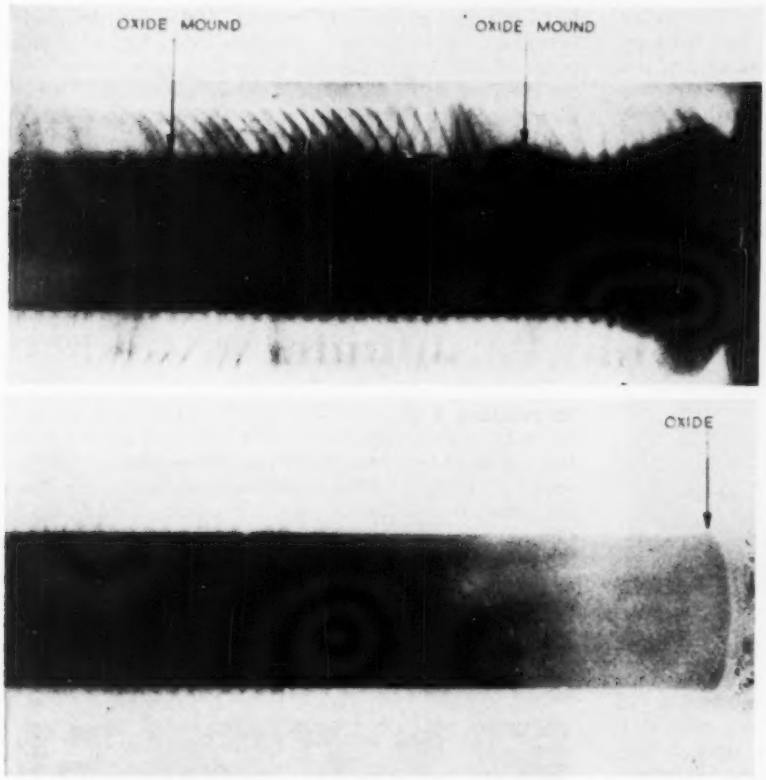


Fig 2. Radiographs of the lower end (top) *and the upper end* (below) *of a leaking fuel element after removal from the reactor*

Our experience with the fuel elements of the second reactor has been broadly similar. However, our experience has so far been limited to about one fifth of the radiation exposure which will be required in the Electricity Authority reactors—when fuel elements should stay in the reactors for four or five years. Experience of this kind inevitably takes time to acquire. We can, however, shorten the time required to obtain this experience by increasing the heat ratings of a batch of fuel elements by using enriched uranium fuel. We are going to use the Calder Hall reactors to obtain this accelerated experience.

We have also gained experience in the magnitude of the CO_2-graphite reaction leading to carbon monoxide. Experiments in the Harwell research reactor BEPO had shown that radiation can increase the rate of the reaction a thousand-fold over the thermal component of the reaction. Experience at Calder Hall is illustrated in Fig 3. You will see that the concentration of carbon monoxide increases on start-up and then flattens off at a fraction of one per cent. This agrees with the predicted result and does not present any problems.

We are also accumulating experience on the rate at which energy is stored in graphite by the displacement of atoms from their normal positions. Samples of graphite are withdrawn periodically and the amount of energy stored is measured. The present indications are that it will be three to five years before the stored energy reaches a level at which it will be advisable to anneal the graphite to release this energy. A method similar to that recently used at Harwell to release the energy in the research reactor BEPO can be used. The Calder Hall design provides for raising the temperature of the graphite by recirculating part of the CO_2 without passing through the heat exchanger. This will allow the energy to be released under conditions of coolant flow which would make any excessive temperature rise impossible. The closed circuit of the Calder Hall reactor provides an additional safeguard. We do not think therefore that the stored energy presents any problem in Calder Hall.

We are also using Calder Hall to gain experience in the power and temperature transients which could follow any fault conditions in this type of reactor. We are also studying the small changes produced by neutron irradiation in the brittle-fracture characteristics of the steel used in the pressure vessel. These studies will ensure that the pressure vessels are at all times operated under safe conditions.

All these investigations are being used to provide information for the design of the next generation of nuclear power stations which are being built by British industry for the Electricity Authorities. The Calder Hall experience has enabled major steps forward in design to be made. Thus the experience of welding on site the large reactor pressure vessels made from steel plate 2 in (50·8 mm) thick gave the boiler makers confidence that they could

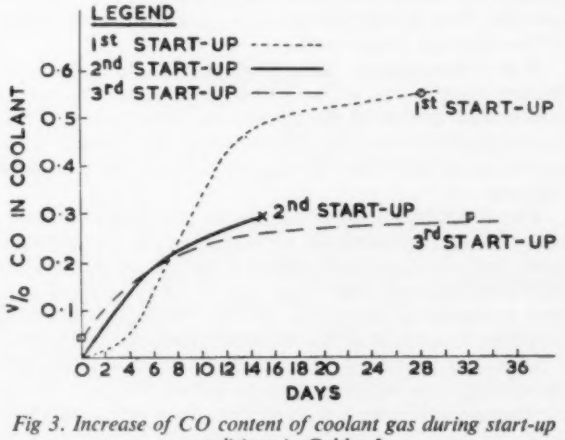


Fig 3. Increase of CO content of coolant gas during start-up conditions in Calder I

fabricate on site pressure vessels of much larger size made from 3 in (76·2 mm) plate. So the Berkeley and Hunterston power stations will have spherical pressure vessels 70 ft (21·3 m) in diameter and the Bradwell station will have cylindrical reactor vessels 50 ft (15·2 m) in diameter. The larger graphite core which can be accommodated enables the amount of uranium in the fuel elements to be doubled. A further advantage comes from the greater wall thickness, since the gas pressure can be raised by about 50 per cent. This, together with an increase of the operating temperature of the fuel elements and improvements to the heat transfer surfaces, has allowed the heat ratings of the fuel elements to be approximately doubled. These two factors together have produced a four-fold

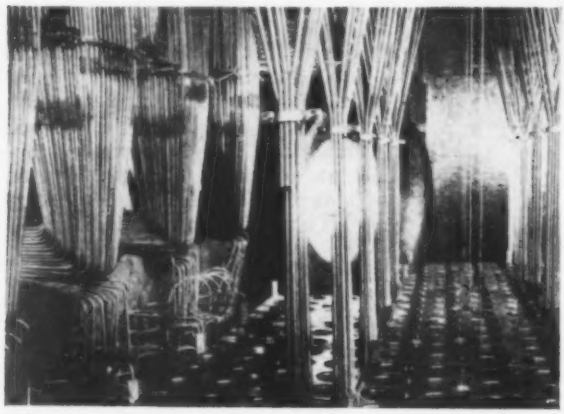


Fig 4. Detectors used for testing for leaks in Calder Hall

increase in output over Calder Hall and the first three stations will have net electrical outputs of between 275 and 300 MW. This development has been carried a stage further in the Hinkley Point power station. The amount of uranium has been further increased by about 50 per cent and the net electrical output has been increased to 500 MW. This increase in output has reduced capital costs by about 20 per cent. It seems likely that this process of straightforward engineering development can proceed further and outputs are likely to increase beyond 500 MW for a two-reactor station. The industrial organizations concerned have said that outputs of 800 MW are possible. This should lead to a further fall in capital costs of the order of 10 per cent.

With these developments the cost of nuclear power in Britain should just about break even with the cost of power from coal-fired stations by the time Hinkley Point is in commission by 1962. Thereafter, nuclear power costs are likely to fall below the cost of power from coal-fired stations.

The Electricity Authorities have predicted, however, that although nuclear power stations, because of their lower fuel costs and high capital costs, will be operated as base load stations, their load factor will fall from 80 per cent to about 70 per cent in the late 1960s. It is essential therefore to achieve a further reduction in capital costs.

Since the proportional cost of the reactor is steadily decreasing, it is necessary also to reduce the cost of heat exchangers and turboalternators to achieve this objective. This can best be done by increasing the temperature of operation of the fuel elements. This will increase the gas outlet temperatures and so reduce the cost of heat exchangers and improve steam conditions, leading to lower turboalternator costs.

The Atomic Energy Authority is developing a prototype of an advanced gas cooled reactor which aims at meeting these requirements. The reactor will have sintered uranium oxide fuel elements, probably sheathed in beryllium metal. Sintered uranium oxide has a melting point of 2400 deg C but has a low thermal conductivity. So the fuel elements will consist of a cluster of small diameter rods. This should allow the heat rating of the fuel to be increased three- or four-fold to the region of 8 MW per ton average. This type of fuel has a good irradiation stability, and US and Canadian experience suggests that a burnup of the order of 8000 MW days per ton should be achievable. The fuel would have to be slightly enriched and beryllium is a more expensive canning material, but taking all these factors into account the overall fuel costs of this type of power station should be about the same as that of the 1960 power stations—about 0·16 pence per unit.

The high ratings, together with the higher operating temperature and improved steam conditions, should, however, enable capital costs of a full-scale station to be reduced to the region of £80 per kW—a further 20 per cent reduction. We believe therefore that when this third generation of nuclear power stations comes into commission in the second half of the 1960s we shall have gone a long way towards meeting the prediction of Sir Christopher Hinton in his Axel-Johnston lecture that by 1970 the overall cost of electricity for nuclear stations would be about 0·47 pence per unit.

The development work to carry out this programme requires the services of about 150 scientists and engineers

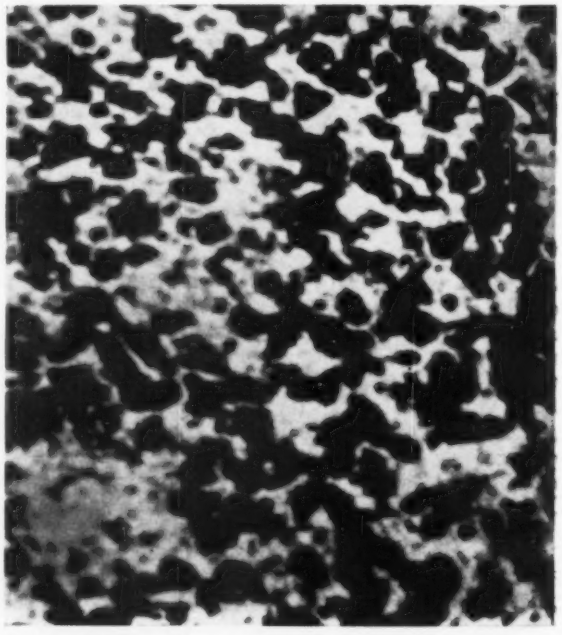


Fig 5. Micrograph of structure after irradiation. Specimen shows 38 per cent decrease in density

of the Atomic Energy Authority backed up by the help of British industry. The Authority is now equipped with three very powerful materials testing reactors: DIDO and PLUTO at Harwell and DMTR at Dounreay. These reactors are provided with rigs and loops in which the behaviour of materials under irradiation is investigated, so that advance prediction of their performance is available to the designers. We are already irradiating in DIDO specimens of uranium oxide fuel elements sheathed in beryllium to study the irradiation stability. These specimens are highly radioactive when they come out of the reactor. We have therefore built new shielded facilities for their examination. Some of these cells are provided with television viewing equipment which enables micrographs of the fuel structure to be obtained after irradiation. We are also studying the CO_2-graphite

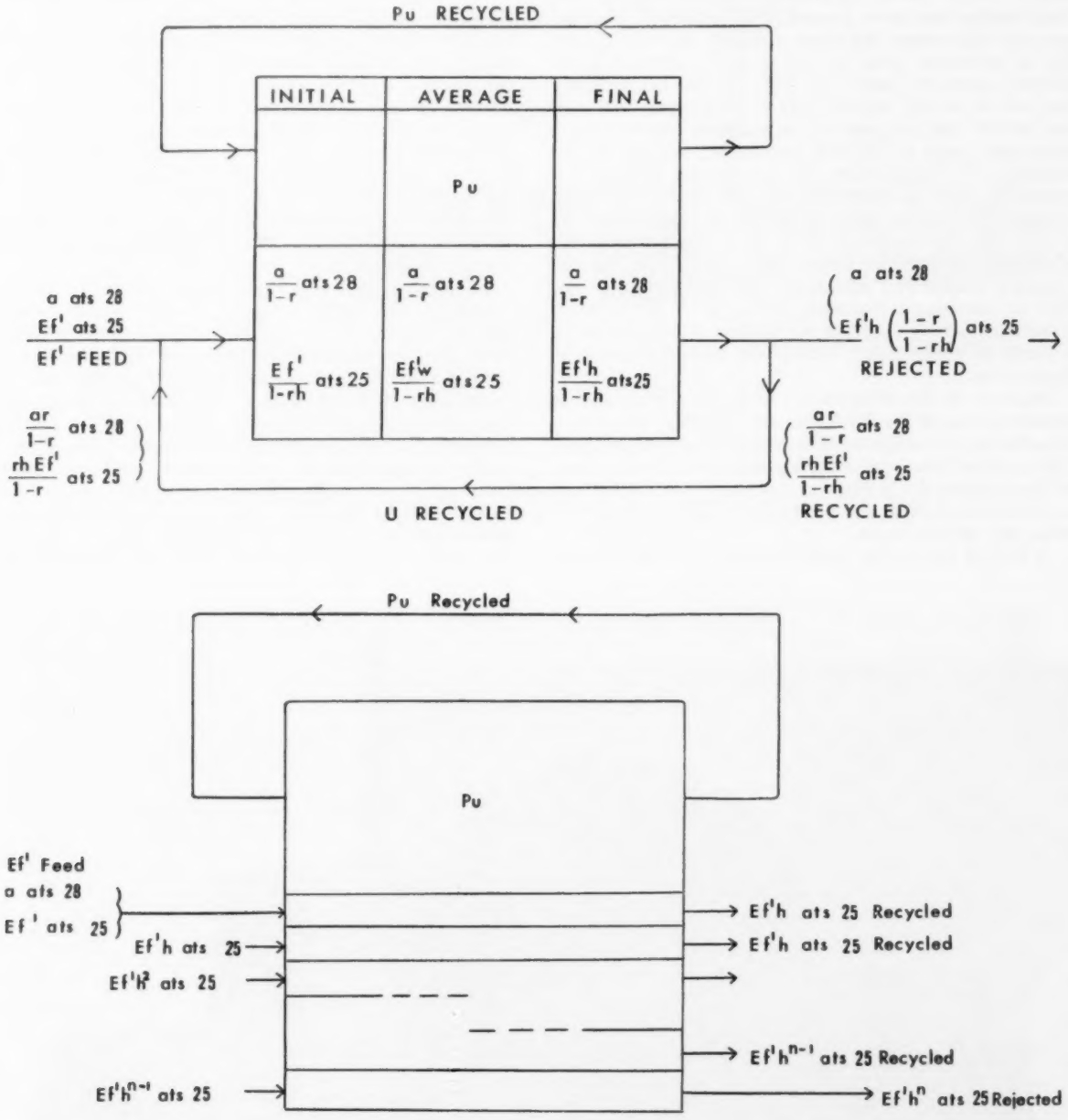


Fig 6. Diagrams of the single uranium cycle (top), *and the multi-uranium cycle* (bottom)

reaction at the higher temperatures which will be characteristic of the AGR (advanced gas-cooled reactor).

The Authority is also building an extensive new plant for converting uranium ore into metallic fuel elements and will later build a plant for ceramic fuel elements. The Chemical Separation Plant at Windscale will also be enlarged to provide a central processing facility for the whole nuclear power programme. By this means very considerable economies of scale will be achieved, since the cost per unit output decreases markedly as the throughput is increased. Thus we expect to be able to supply natural uranium Calder type fuel elements for the early stations in the UK nuclear power programme, and also for similar stations exported to overseas countries, at a maximum price of £20,000 per tonne, subject to cost variations in future years. We also expect that the repurchase price of spent fuel elements which will have achieved the alloted span will be not less than £5000 per tonne. This takes account of the fact that the spent fuel elements will contain rather more than 2 kg of the valuable nuclear fuel plutonium. We shall be able to use this by recycling it together with some of the depleted uranium, thereby reducing the natural uranium feed by a factor of about three. This is the basis for the buy-back price.

We may on the other hand use the plutonium fuel in small reactors of the PWR (pressurized water reactor) or organic liquid moderated type for use in propulsion units. The potential heat content of a gram of plutonium, worth in future about £5, is equal to that of 1·7 tons of fuel oil, so there is a challenge to propulsion reactor designers to make use of plutonium.

A further use of plutonium is to feed it to fast breeder reactors which after an initial charge of several hundred kilos will thereafter produce 50 to 60 per cent more plutonium than they consume. We are bringing into commission this year at Dounreay the world's first large-scale experimental fast breeder reactor. So we expect during the next few years to acquire experience in its potentialities.

We have not lost sight in the UK of other promising routes to nuclear power and we are carrying out an intensive research study on the heavy water, gas-cooled reactor. This reactor shares with the graphite moderated gas-cooled reactor the advantage of using natural uranium or near natural uranium fuel. It has very good nuclear properties, which is good for fuel costs, and it has a smaller size than the graphite moderated reactor, which is good for capital costs. The economic prospects of this reactor seem to be about the same as those of the AGR. Technological factors will probably decide which of these is likely to lead in the reactor race of the late 1960s.

In carrying out this programme of the development of nuclear power, the UK Atomic Energy Authority and British industry have established a partnership in which development work is effectively shared, while the operating and designing experience of the AEA is made available to industry. Reactor physics experiments to determine the optimum lattice parameter of future reactor designs are carried out in common in the Authorities' laboratories and other development work is carried out jointly in the laboratories of industry. Fuel element cans are designed by the individual groups, so there is an important element of competition in achieving maximum heat ratings, but the fuel elements themselves will be fabricated by

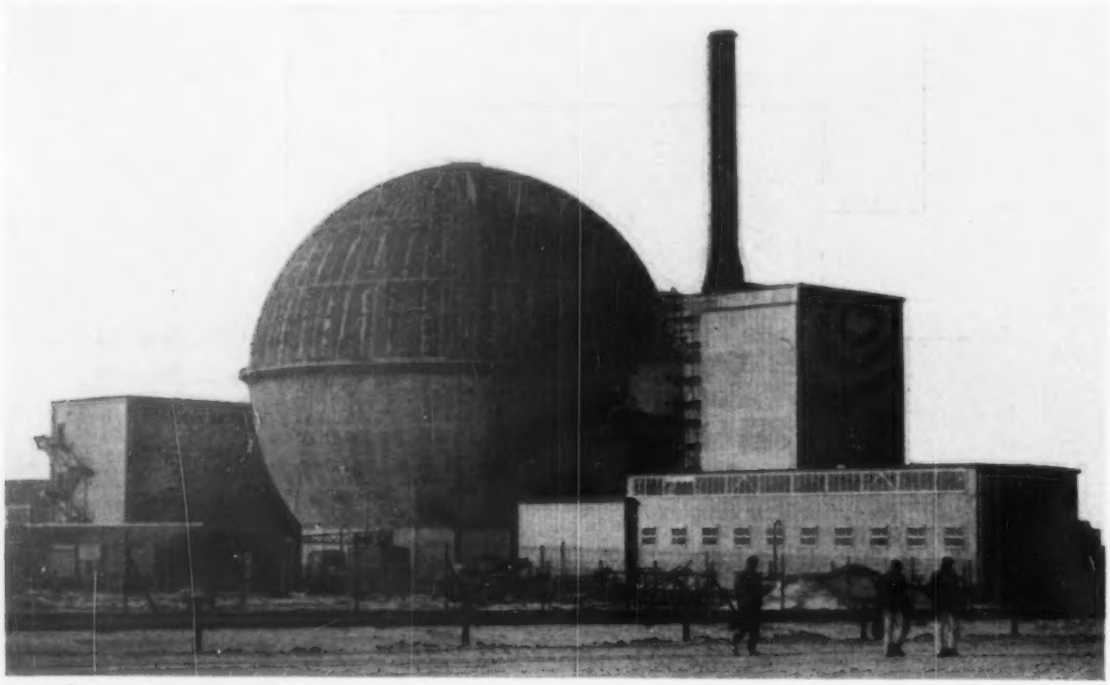
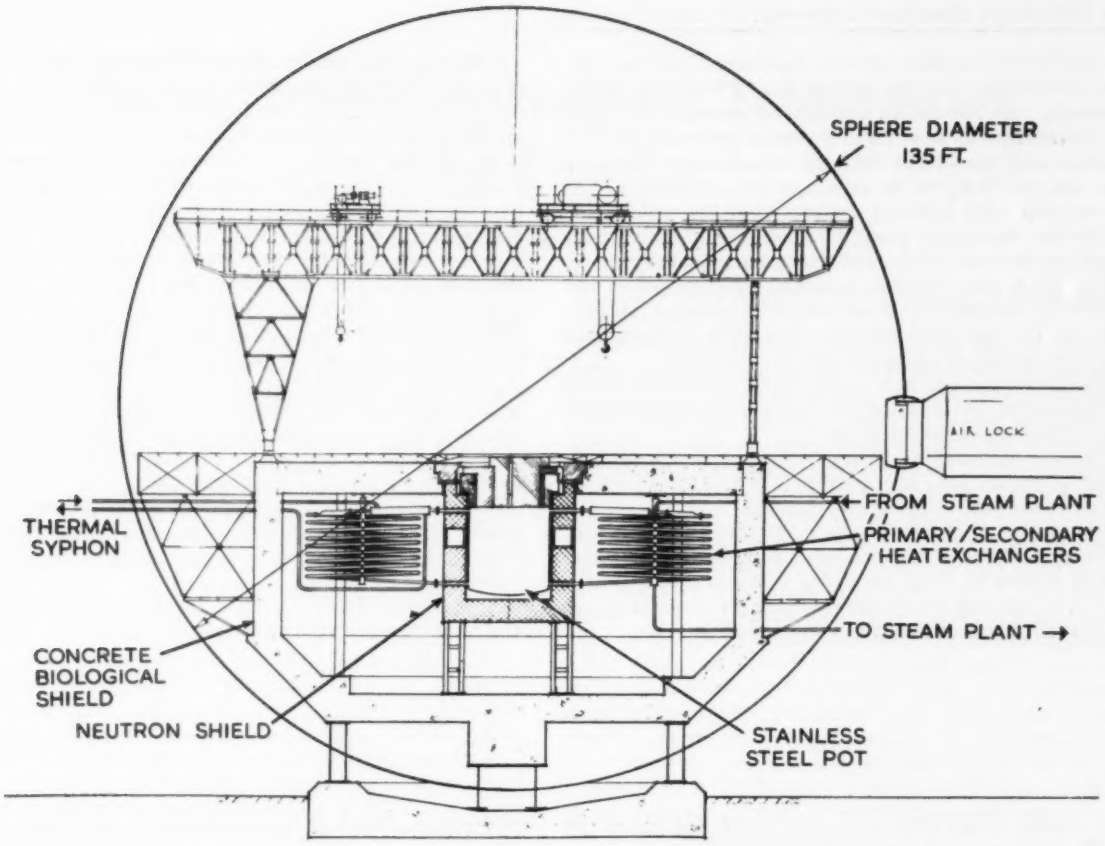


Fig 7. Exterior view of Dounreay—the world's first large-scale experimental fast breeder reactor



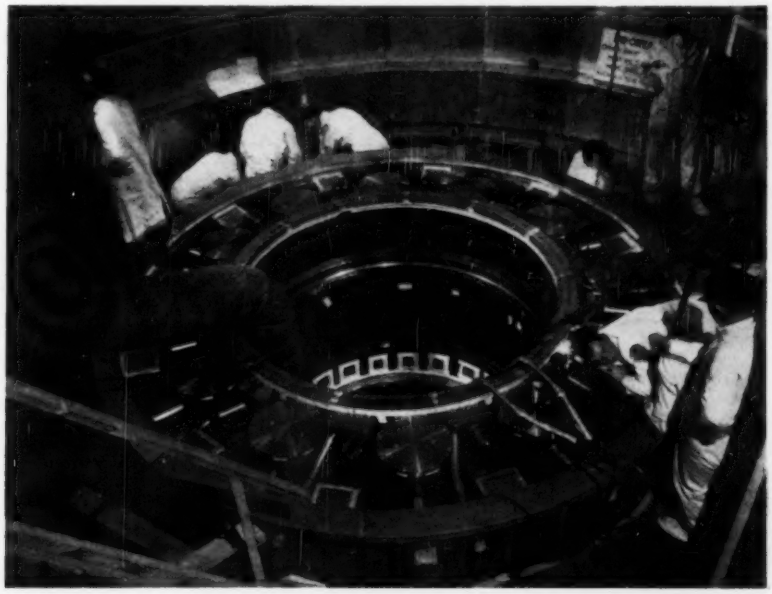


Fig 8. Two more views of Dounreay. Above is a schematic diagram of the internal layout inside the 135 ft (41 m) diameter sphere. Below is a picture of the fast reactor vault nearing completion

the Authority in their central facilities. This has the great advantage that the central testing facilities of the Authority can be used to the best advantage. Although the Authority has now three powerful materials testing reactors and associated shielded examination facilities, they are still likely to be extremely heavily loaded. The partnership with industry ensures that the volume of irradiation testing is greatly reduced over that which would be required by four or five independent groups.

The AEA also provides a consultative service to the Electricity Authorities. It advises the Electricity Authorities on the technical aspects of tenders received and provides advice on siting and safety problems.

The Authority has now a central Safety Branch which is responsible for studying the safety aspects of reactors and approving operating codes.

These consultative services are being made available to other countries who are interested in the possibility of constructing British designed reactors.

We believe that Britain, through this partnership of industry and the AEA, can offer a powerful, well-integrated service to other countries which is unique in the world. In this way we are making a major contribution to the development of nuclear power in the world.

I have not had time to say anything about the exciting prospects of obtaining power by the fusing together of deuterium nuclei. The stars have been doing this for several thousand million years, so it is natural and exciting to try to emulate their performance by heating up deuterium gas to high temperatures by electrical discharges. Our research project ZETA is an encouraging first step on the way. We have produced a stable discharge channel carrying 200,000 A for several milliseconds and expect to improve greatly on this performance as we are able to feed in more and more energy. At present the energy released by the fusion reactions is less than a millionth of the energy input. We expect, however, to be able to raise the temperature beyond the few million degrees we have so far reached to tens of millions of degrees. To reach the break-even point we shall need to reach temperatures of over 100 million degrees in deuterium and 40 million degrees in a deuterium-tritium mixture.

I do not think fusion reactors will supplement fission reactors for at least twenty years, and it may be much longer. But certainly it is a fascinating new field of research.

The model of ZETA in the Exhibition well illustrates the principles on which we are working.

Sir John Cockcroft's paper was followed by a film 'How a Thermal Reactor Works', showing the operation of the Calder Hall plant.

That concluded the second (and last) business session, and the Conference was then formally closed by the President, Sir Vincent de Ferranti.

In the evening, members of the Conference attended a reception held in the Exhibition 'Palais de l'Elégance'.

Recent Trends in Overhead Transmission Line Practice

N. G. Simpson, MICE, MIEE, ACGI*

INTRODUCTION

THE technique and practice of overhead electric power lines have expanded progressively over the last fifty years, from small beginnings involving occasional low-load, small-voltage, short-distance lines on short-span wood pole supports to modern extra high voltage and load capacity lines on long-span, lattice steel towers traversing hundreds of miles of territory in all parts of the world. This expansion reflects the continuous increase in the demand for, and supply of, electricity, and in particular the intensive development in rural areas. The development in bulk transmission follows the adoption of the principle of interconnexion of available sources of power and the use of direct overhead line links between remote hydro-electric resources and industrial areas of consumption.

The UK possesses the largest integrated supply system in the world. Moreover, it is representative of every facet of modern electricity supply engineering, built progressively to maintain a highly efficient supply to a concentrated consumer population equally representative of known forms of load. This now fully coordinated system was first started by the inauguration of the 132 kV grid system some thirty years ago, the object of which was to rationalize and run selectively the generating resources of the country, and by interconnexion to reduce substantially the amount of spare plant, in the expectation of cheapening supplies to an extent that would more than offset the cost of the interconnecting grid. These expectations have been more than fulfilled, and in addition the grid more than proved its usefulness in the maintenance of supplies during the last war.

The Super Grid

In 1948 the then newly formed British Electricity Authority and fourteen Area Electricity Boards took over the whole of the generation and distribution resources and accompanying grid network. At the present time the total installed generating capacity is over 20,000 MW—having more than doubled in ten years. A 275 kV superimposed system, known as the Super Grid, is at present in the course of construction, ultimately to consist of over 1000 route miles of overhead line, a portion of which will ultimately operate at 380 kV. The main purpose of this is to feed into the existing grid network supplies which can be more economically generated in the extensive Midlands coal areas. The existing 132 kV grid consists of over 4500 route miles of overhead line on lattice steel supports. In addition there has been a continuous reinforcement and expansion deep into the rural areas, with primary and secondary distribution overhead lines at 66, 33, and 11 kV.

At the turn of the century there were only about 50 miles (80·5 km) of overhead line in Great Britain. In 1914 this had risen to approximately 1000 miles (1609 km). At the present time the route mileage exceeds 50,000 miles (80,465 km).

This expansion, intensified over the last 25 years, is similar in greater or less degree in the principal industrial countries of the world. During the post-war period there has also been a deliberate policy to utilize the available power resources of undeveloped areas. Progress has been substantial, with the inevitable follow-through of mostly overhead transmission and distribution. The extent of this overseas development is clear from an analysis of the World Bank loans for the past year where, out of a total of 2528 million dollars, 869 million dollars—the largest allocation—was directed to electric power. The form in which the available energy is deployed is in almost every case by overhead lines, especially in sparsely populated areas where the greater distances and smaller load concentrations render the alternative form of underground cable economically prohibitive. Even with overhead lines there is always the greatest pressure on economical construction and—paradoxically enough, because of the extended areas of such supply systems—still more emphasis on reliability of supplies to keep maintenance expenditure to reasonable proportions.

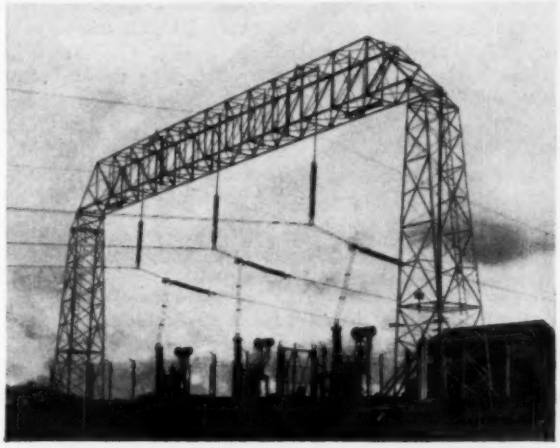


Fig 1. Central Electricity Generating Board outdoor ehv overhead experimental station at Leatherhead, Surrey

Overhead line practice is principally one of civil and structural engineering in dealing with supporting structures and foundations. Mechanical engineering aspects enter into the mechanics of the suspended conductors and insulators. Electrical considerations surround the basic circuit characteristics and insulator design, and important supplementary issues arise from the performance of conductor fittings in service resulting from the combined effects of current loading, mechanical stress, and

* British Insulated Callender's Construction Co Ltd.

extraneous climatic influences. Finally, the overall design is influenced by the extent and need of circuit protection from the effects of lightning.

Altogether, the engineering of overhead transmission systems covers the widest scope which becomes fully extended as system voltages increase and, with this, a corresponding importance in the continuity of supplies of large bulks of electrical power. The highest ac system voltage in existence to-day is at 380 kV. We are within measurable distance of three-phase long-distance overhead ac circuits which will operate at 0·5 million volts and transmit up to 1 million kVA. The vocation of electric power transmission engineering is thus one that in recent years has acquired a significant and prominent place in the overall field of engineering.

Specialized design requirements

Transmission line design is controlled throughout by the fact that live bare conductors are suspended above ground under conditions of continuous and variable mechanical stress, as well as being exposed to all forms of climatic conditions of wind, ice, and lightning. It is to a large extent a specialized subject with its own design code. It is for that matter unlike most conventional civil engineering structures where the dead load is large compared with the live or external loads. Designers are primarily concerned with the proportionally large external loads on, and the variable forces arising from, the suspended conductors. These external loads in higher latitudes are those of wind and ice. In tropical and sub-tropical regions there is no ice load and thus the one arbitrary factor in external load assessment is eliminated. The aspect of corrosion has also an important bearing on

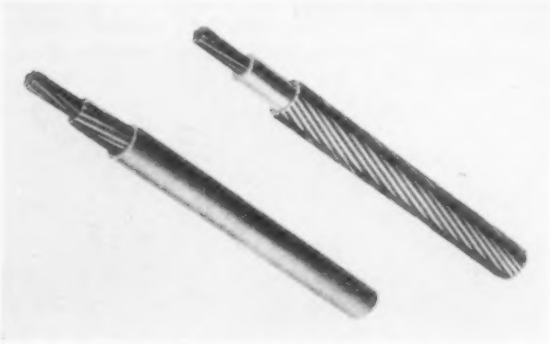


Fig 2. Samples of extruded sheath steel-cored aluminium conductors

design practice, with its dual effects on all materials and its secondary influence on the efficiency of current-carrying parts. Atmospheric contamination can seriously affect transmission line performance, and especially the insulation. This problem is more severe in the UK, with its heavy concentration of industrial and marine contamination, than in most countries in the world.

General expansion, rising material and construction costs, and a high proportion of world development in rural and sparsely populated areas have stimulated electrical and structural research in many countries to find out more about the natural phenomena which so influence transmission line design and performance. Hitherto accepted and sometimes arbitrary rules and safety margins are under review—all tending towards justifiable economies without compromising performance reliability. Operational experience, especially in overseas territories, is much sought after so that it may be ploughed back for future improvements.

British experience and technique in the field of overhead transmission are of a high order, since they have been concerned both with their own large, representative and up-to-date supply network and with those in many overseas, and especially Commonwealth, countries.

Some of the important and outstanding electrical and structural problems in overhead line technique may now be outlined.

ELECTRICAL ASPECTS

Standard British nominal three-phase ac system voltages are:

400/230 volts	MV distribution
11 kV	HV distribution
33 kV	HV distribution and subtransmission
66 kV	Subtransmission
132 kV	Grid transmission
275 kV	Super grid transmission
380 kV	Future super grid transmission

A small number of circuits at 6·6 kV and 22 kV are in operation, but new lines conform to the preferred voltages. Both 66 kV and 88 kV are popular subtransmission voltages in South Africa and Rhodesia. 220 kV transmission lines are in use in India and New Zealand, and 330 kV lines in America and Australia. This voltage has been adopted in Rhodesia for the Kariba scheme.

Conductors

Electrically, overhead line conductor sizes may depend upon temperature rise, voltage-drop or regulation, power loss; and with ehv lines, corona and radio interference, as well as system steady state and transient stability.

For lines up to 33 kV, the size is influenced by temperature rise for short heavily loaded lines, and by voltage-drop for longer lines. Above this voltage corona loss becomes a significant factor, and the minimum size from this consideration is about 0·035 in² (22·6 mm²) for 66 kV lines, 0·125 in² (80·6 mm²) at 132 kV, 0·2 in² (129 mm²) at 220 kV, and 0·35 in² (226 mm²) at 275 kV. At higher voltages single conductor diameters may be too large to be economical. Twin 0·4 in² (258 mm²) SCA conductors per phase at 12 in (305 mm) horizontal spacing have been used for those British 275 kV lines convertible to 380 kV working, when the corona loss and radio interference level will still be within acceptable limits. Generally a corona loss of 0·5-1 kW per three-phase mile under fair weather conditions indicates a satisfactory low level of radio interference.

The steady state and transient stability of a line depends upon the system reactance between the sending and receiving ends. Up to 66 kV there is no problem, but where lines also tend to become longer, the proportion of line system reactance becomes significant. For ehv lines, stability alone decides the maximum amount of transferable power. A reduction in reactance can be achieved by using a two, three, or four conductor 'bundle'. Three conductors per phase have been considered for ehv lines in Sweden and Russia, but generally the reduction in reactance resulting from three conductors instead of two is not significant in relation to the additional cost.

Series capacitors on the other hand reduce line reactance, voltage-drop, and improve voltage regulation

smoothly and automatically. British grid lines are comparatively short with little call for series capacitors, but in America, Sweden, Russia, and Japan series capacitors have been used with advantage on long lines. British capacitors are in operation at 88, 33, and 11 kV in Southern Rhodesia.

Series capacitors are in the future likely to be considered automatically with line electrical design in the interests of overall economy and efficient operation. The percentage line compensation varies, but 50 per cent reactive compensation for ehv lines, and up to 100 per cent or more for lower voltage lines, are normal values.

Thus the selection of conductor sizes is relatively straightforward for lines up to 66 kV or so, based on established voltage-drop, power loss limits and the economics of capital and running costs. For higher voltage and long-length lines the selection is more complex and is related to operational aspects of corona, radio interference, stability and protection.

Insulation

Overhead line insulation must withstand the effects of internal and limited external overvoltages and contamination.

Internal overvoltages are caused by switching and faults, the magnitude depending on the system electrical constants (resistance, reactance and capacitance), the nature of load (inductive, capacitive or resistive), the type of neutral earthing (solid, resistance, or Petersen coils), and the type of protective gear (fuses, circuit breakers or autoreclosures). Surges are more severe with fuse protection, Petersen coil earthing, and highly inductive or capacitive loads, and such high-frequency surges may reach 6-7 times the normal line-to-neutral voltage. With Petersen coils, the healthy phases are raised to $\sqrt{3}$ times the normal line-to-earth voltage with an earth fault.

External overvoltages due to lightning, on the other hand, are unidirectional impulse waves with a steep front and possible durations of 5-1000 microsecs and magnitudes up to several thousand kilovolts.

Insulation may normally withstand internal overvoltages but it is impractical, if not impossible, to design against the full range of external lightning overvoltages. It may withstand lightning overvoltages up to a predetermined level, beyond which it becomes uneconomical to provide the necessary insulation, and faults must be then accepted, with corresponding care to prevent or minimize consequential damage.

Line insulators are of two basic forms:

(*a*) Pin or post insulators, generally suitable up to 66 kV, but mostly used for voltages up to 33 kV.

(*b*) Suspension or tension cap and pin insulators built up into variable length chains for the higher system voltages.

Since the withstand voltage of insulators depends on their external shape and surface conditions, development has always been directed towards shapes which will retain insulation values under fog, rain, and contamination conditions. Anti-fog insulators used extensively in the UK achieve this by a large and protected surface leakage path.

Industrial and marine contamination is severe in the UK and in many parts of North America to an extent where even oversize anti-fog insulators are inadequate. Live insulator washing with high-pressure water jets has sometimes been necessary, and this is inconvenient and costly.

In recent years there have been successful trials in the UK and elsewhere of applied silicone grease coatings on insulators in severe conditions. Insulation levels have been retained for over a year with a very thin layer of this substance. Petroleum base jellies have also given satisfactory results on British 132 kV lines. Grease also tends to reduce radio interference.

Lightning protection

Lightning intensity is comparatively low in Britain and on the Continent, and conventional protective methods such as overhead earthwire shielding have generally proved adequate. In tropical and sub-tropical countries lightning intensity is much higher.

The nature and effects of lightning are now more clearly understood than they were twenty years ago, and lightning aspects are now considered automatically in line design and predetermined economic protective levels are generally established. Line outage rates can be reasonably predicted if the impulse voltage level, footing resistance, and lightning intensity are known.

Present protective methods may be summarized as follows:

(*a*) Substation and terminal equipment: Equipment designed to withstand impulse voltages established by the International Electricity Commission. Outdoor station equipment is shielded by overhead earthwires, to intercept direct lightning strikes. Incoming surges by the overhead line wires are drained to earth through surge diverters for important stations, and simple spark gaps in other instances.

(*b*) Ehv transmission lines: The provision of overhead shield wires to intercept lightning and drain it to earth. Supporting insulators to have an impulse value such that back flashovers from tower steelwork (which is raised to a high potential when lightning current is flowing through it) to conductors are avoided for the majority of strokes. The tower footing resistances are reduced to an acceptable value by installing earth rods or buried counterpoises. In regions of high soil resistance, double earthwires with continuous counterpoises are sometimes warranted.

Insulation levels, earthwires, and acceptable values of footing resistances are a matter of economics. Generally an outage rate not greater than 3-4 per 100 mile/year is a suitable aim.

(*c*) Distribution lines: There are two broad line classifications.

(i) Lines with overhead earthwires. Substantially the same procedure as (*b*) above is adopted. The economic level of insulation is basically low, so that a much higher outage rate must be tolerated. Such protection is more effective with low soil resistivity and suitable footing resistances secured economically by a small addition of earth electrodes.

(ii) Lines without earthwires—unearthed type of construction. Conductors, insulators, and supporting steelwork are mounted on unearthed wood poles with no overhead or underslung earthwires. The high insulation value of the wood pole normally prevents lightning faults to earth, although such lines remain vulnerable to phase faults.

A prominent example of unearthed construction is the 11 kV horizontal conductor configuration wood pole line specified in BS 1320: 1946. A considerable mileage has been erected in the UK and many overseas countries. Operation records show a very satisfactory performance,

both from lightning and from earth faults caused by bird trouble.

Altogether, overhead line damage from lightning surges is negligible, but the subsequent power current following the ionized path is the cause of damage. Protective arcing horns on insulator strings and bushings are normal, but the modern use of high-speed circuit-breakers and auto-reclosures are proving more effective because faults can be cleared within 3-5 cycles of their inception.

Line lightning outage rate, as already stated, depends largely upon its insulation impulse level, and the primary insulation (*i.e.* the insulation in direct contact with the live conductors) cannot be increased beyond an economic limit. Wood, however, has a reasonable impulse withstand voltage about 25 kV/ft (30·5 cm) when wet, but inadequate power frequency insulation value. With glass or porcelain primary insulation in series with secondary wood insulation, the line impulse level can be substantially raised with appropriate power frequency safeguards.

Lines employing this principle, with wood pole supports and crossarms, have been used for extra high voltage. Steel tower lines with wood crossarms are not uncommon. Operational records in the USA have proved the effectiveness of this form of construction against lightning.

In spite of the satisfactory results obtained with wood, the search continues for a more dependable and superior material for secondary insulation. Resin bonded fibreglass components in the form of spindles for pin insulators, crossarms, poles, and perhaps complete structures, may in the future contribute much in reducing lightning outages.

STRUCTURAL CONSIDERATIONS

Since the structural stability and working efficiency of overhead lines are also essential for public safety, minimum load requirements for design and stipulations in such matters as clearances and earthing, must be controlled everywhere by statutory regulations. In the early days of development, a naturally conservative attitude was adopted. As a result of experience over the last fifty years, however, structural relaxations have been progressively applied both in loadings and direct safety precautions. Such matters are still under review in many countries. The last war stimulated in the UK the adoption of temporarily relaxed structural loadings in the interests of economy, and the experience was so satisfactory as to warrant a post-war review towards continuing these relaxations in permanent form.

Conductors

It was at this time that British engineers concerned adopted a new attitude of mind to the subject of ice loading on conductors—the one uncertain and arbitrary factor in the assessment of external loads. It was known in any case that ice thickness can, on occasions, build up to abnormal amounts to an extent which cannot economically be allowed for in design. Apart from this, the question of ice loading creates an anomalous situation in most regulations due to the particular mechanics of suspended wires. It is usual, for example, to specify a minimum radial ice thickness, such as $\frac{3}{8}$" (9·5 mm), on the conductor corresponding to its maximum working tension, which is a proportion of its ultimate strength depending on the factor of safety specified, *i.e.* 2·0 or 2·5. With this stipulation, and depending on the span and other factors, the resulting amount of ice that conductors can support at their ultimate strength is very varied. In other words, a stipulated and constant ice thickness at an intermediate tension is no criterion of the conductor's capabilities of sustaining load at ultimate stress. In brief, the new outlook was therefore to impose a suitable and realistic superimposed load at what is regarded as the practical ultimate strength of the conductors—a known load beyond which the conductor may be expected to break. Supports and fittings are then designed on the basis of ultimate loadings and not, as hitherto, on an arbitrary working load basis. Draft British regulations have been framed on this unusual basis and are likely to be implemented in the near future.

In ice-free countries the external loads are more determinable. Records of maximum wind velocities are usually available. In any case there is no wide margin of uncertainty as with ice. Transmission lines are of lighter construction. Important full-scale experimental work in recent years in a number of countries, including Australia, has shown that the maximum wind velocity front acting on a transmission line is comparatively small, to an extent that a reduction factor on assumed maximum wind velocities is justified when considering wind loads on spans in excess of 700 ft (213 m). Such relaxations have been applied in varying degrees in several countries, notably Sweden.

Unlike insulated and buried cables, overhead conductors must have the dual qualities of high conductivity and mechanical strength—the latter to avoid excessive sags and high supports which tend to uneconomic construction. Hard-drawn copper was used extensively years ago for the prevailing short-span lines because of its high conductivity, reasonable tensile strength, and cheapness.

Following the step-up in system voltages, the adoption of longer span lines, and especially the post-war rise in the price of copper, there has been in recent years a greater use of composite steel-cored aluminium, plain aluminium, and aluminium alloy conductors. SCA and alloy conductors are of high tensile strength adaptable for long spans, while aluminium of lower strength is mostly confined to small-span distribution lines, although in ice-free regions and in special circumstances it can economically be used on long-span lines. SCA conductors were chosen for the 132 kV grid in the UK in the late 20's and this policy has been retained throughout, including their use for the 275/380 kV super grid. The price differential between copper and aluminium has narrowed in recent months and if this trend continues, copper will return to favour in the sphere of lower voltage lines.

Composite conductors consisting of either copper, aluminium, or alloys of these and steel, have a basic disadvantage because of electrolytic corrosion, the intensity of which depends on atmospheric conditions and the measures adopted to overcome it. In rural and uncontaminated air there is no problem, but in industrial or marine conditions the effect can be serious. Because of severe conditions in many parts of the UK this problem of corrosion has been the subject of exhaustive study. Protective measures in the application of protective greases have been highly successful, such that the continued use of such conductors has been maintained. An alternative method, ensuring complete protection, was applied to a section of grid line in the form of an extruded homogeneous aluminium sheath applied in one case to the steel core, and alternatively as an overall external

layer. Field trials over two years have proved its mechanical and protective efficiency.

The other principal and outstanding problem with all conductors, especially those with a large diameter to weight ratio on long spans, is mechanical vibration. A considerable amount of experience, test data, and results of studies are available. The cause of most vibration phenomena is eddies due to light winds, the energy of which is conveyed to the conductors. The effects are intensified at higher mechanical tensions and mechanical damage may result. Remedial measures take the form of conductor tension limitation on the one hand, and/or the application of dampers to absorb the energy of vibration. Even to-day the technique on vibration is still to a large extent arbitrary, and still more knowledge is required to master completely this phenomenon both to avoid faults and to give more design flexibility.

Reference has already been made to the post-war use of bundled or multiple conductors to reduce reactance and corona loss. When two or more conductors per phase are used for this purpose, spacers are necessary to avoid mid-span contact, and this presented important mechanical problems in ensuring operational efficiency under continuous dynamic and climatic conditions. Expensive and elaborate full-scale test installations were installed in France, USA, and at the CEGB Experimental Research Laboratories at Leatherhead, Surrey, to study the combined electrical and mechanical characteristics of this new conductor formation. The results were used to good effect in the subsequent large-scale ehv transmission projects in these countries.

Conductor fittings, particularly those under mechanical tension such as dead end clamps and mid-span joints for composite conductors, must operate efficiently and continuously, retaining their full tensile strength, conductivity, and freedom from contamination and ingress of moisture. In recent years these requirements have been satisfactorily met by the compression type sleeve joint technique which is gradually being adopted for most conductor fittings in both transmission and distribution work. The development of compact manually operated hydraulic presses has contributed largely to its success and reliability.

The mechanical design of insulators is now stable, with no important and outstanding problems. The vital mechanics surrounding the connexions of the porcelain or toughened glass insulating medium to its metallic attachments have been overcome, so that there have been progressively higher mechanical load ratings available with stringent electrical stipulations. Toughened glass cap and pin ehv insulators have made rapid strides in the United Kingdom since the war and have been used on many overseas projects, notably the 900 mile (1450 km) 330 kV Kariba overhead transmission system under construction in Rhodesia.

Structures and foundations

Overhead line supporting structures may consist of either wood, reinforced concrete, single steel tubes, or galvanized lattice steel towers. Pressure-impregnated creosoted wood poles are used mostly for medium and high voltage lines and represent the cheapest and most adaptable structural form in combination with stays at angle and terminal positions. They are vulnerable to termite attack in tropical countries, but research and experience have proved the effectiveness of pressure-impregnated creosote. Large quantities of wood poles are installed in Central and South Africa every year, a measure of the confidence in this treatment. Above all, the wood insulation values are used to advantage in operation.

Concrete poles are not used to the same extent as wood or steel. Even when pre-stressed, the weight is appreciable and they are less adaptable in application than wood. Nevertheless, when alternative material is expensive and large quantities are involved, a pre-stressing plant may well be justified. Long life is assumed; there is no corrosion and, therefore, reduced maintenance.

Galvanized and bolted lattice steel towers are invariably used for important ehv long-span lines, except where steel is expensive or large stocks of indigenous high and stout wood poles are available. Transmission steel tower design over the years has grown into a specialized and highly competitive technique, built up principally from the long-standing and continuous practice of full-scale type testing. This applies especially in the UK, where one installation in particular at Hereford has been in continuous operation for over twenty-five years. The majority of the tower types used on the British Grid and a considerable number of towers for overseas schemes, notably India, have been tested at this establishment.

Open-hearth steel is used almost exclusively for British towers, since its inherent ductility facilitates fabrication. This does not follow with steel made by other processes and embrittlement may result from cold working, such as the punching of holes. This problem is serious enough in such cases to warrant a certain control on both steel characteristics and subsequent fabrication practice.

Fig 3. Side bearing tests on single concrete block foundations at Chiddingfold, Surrey

High-tensile steel has been used extensively for many years in towers of British design, resulting in appreciable economies in weight and cost. Overall, in this highly competitive field both at home and overseas, British designs compare favourably in weight and performance with any in the world. Tests consistently show ultimate strengths with narrow margins of about 2·5 per cent above design values.

The contrast between home and equatorial conditions is shown by two illustrations of comparable double-circuit intermediate 132 kV towers in Britain and Uganda. The absence of ice loading in the Uganda tower is reflected in its more slender form, while the insulation and live metal clearances are greater. These characteristics, with the double earthwire, reflect the means adopted to provide greater immunity from lightning outages.

Foundations are not subject to an exact technique as are the structures which they support. Unlike a bridge or a large building, a considerable number of independent structures is involved covering a wide extent of territory and, therefore, types of soil. Elaborate soil investigations are impracticable and footings must conform to a certain amount of standardization. Margins of safety, therefore, tend to be higher for this reason and to offset a certain amount of uncertainty in soil behaviour. In any case the basic character of the soil medium does not allow an exact assessment of its capabilities to resist the forces imposed upon it. Nevertheless, as line foundation installation costs are high there is much incentive to explore every aspect of foundation performance, and active research continues in many countries. For narrow-based supports, single-block side bearing foundations are usual, and independent uplift and thrust footings for wide-based lattice steel towers. The design technique for these two prevailing types are different—the former concerned with resistance to overturning, and the latter principally with uplift and downward thrust.

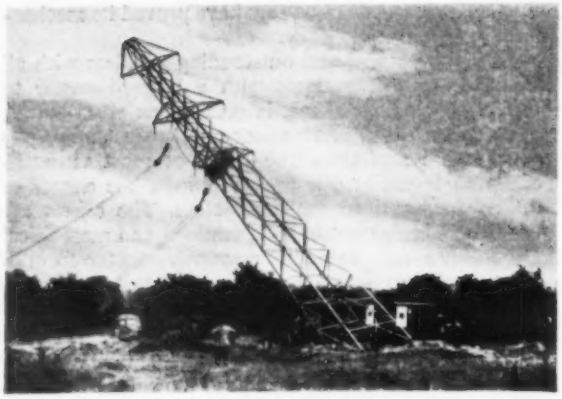


Fig 5. Overturning test on combined 66 kV lattice steel tower and foundations near Woking, Surrey (Electrical Research Assn)

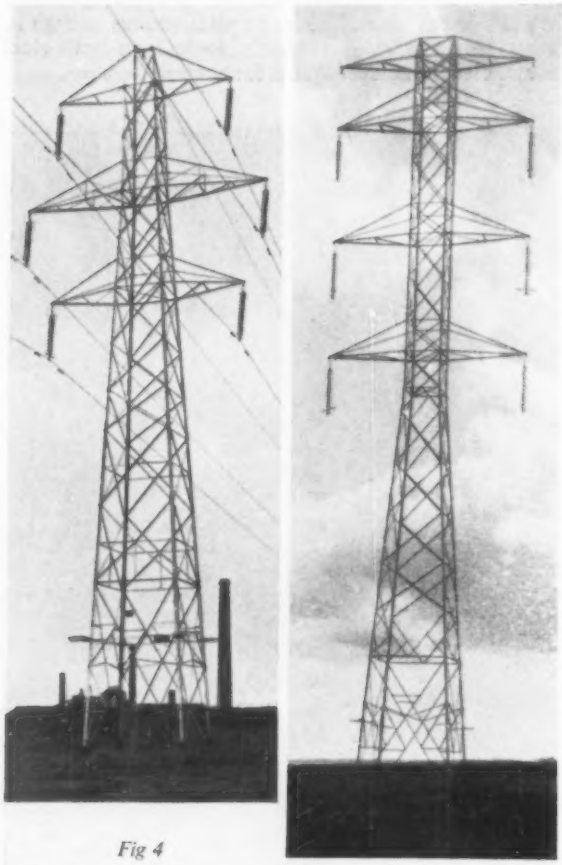


Fig 4

132 kV double-circuit straight-line lattice steel towers
(Left) *British Grid (CEGB)*
(Right) *Uganda (Uganda Electricity Board)*

Full-scale tests have been carried out in the UK recently on both types. The Electrical Research Association has conducted tests on some existing twelve-year-old 66 kV steel towers marked down for demolition, including uplift tests on individual footings and overturning tests on composite towers and foundations, the importance of which lies in the unusual approach of testing footings free from the implications of newly installed foundations.

Another significant point marking the importance of foundation research results from the investigations into wind load on transmission lines, and this is tending towards the establishment of more realistic loadings. The extra margins of strength arising from the adoption of conservative wind loads will be reduced and foundations more likely to incur the loads for which they are designed; hence more should be known about soil technology and foundation performance.

Construction

Erection practice is largely influenced by the nature of the terrain and the extent to which, for example, mechanization can usefully be employed. In the UK, with its many boundaries and high cultivation, lack of manœuvrability and risk of crop damage prevents large-scale mechanization—at least for foundations. There is generally less restriction overseas, but on the other hand labour is usually less expensive, a factor which may outweigh the costs and greater speed of mechanization. Mechanical plant in any case must be used at a high load factor to offset its heavy capital cost, maintenance and depreciation. The power and scope of mechanical earth boring machines has increased in recent years and they can effect appreciable foundation savings, assuming an uninterrupted work programme. Most steel tower footings in

the UK are of the formed concrete pyramid type in which the steel stub is totally enclosed. Apart from being comparable in cost with the alternative steel grillage footing, the stubs are protected from corrosion.

Transmission line construction can be segregated into distinct operational phases: *i.e.* survey and profiling, marking out, foundation installation, tower erection and conductor stringing, the character of each being entirely different. With a long 50 (80·5 km) or 100 mile (161 km) line, however, each operation has to be carefully planned and coordinated to ensure, for example, the delivery of large quantities of piece small material and the correct deployment of labour. Altogether, the cost of overhead line construction could be substantially reduced if complete continuity of work could be assured, but this is seldom possible.

SUMMARY

Many thousands of miles of ac overhead electric power lines are in service at all system voltages all over the world, the design and installation practice of which present such marked differences when compared with that for conventional structures because of the important electro-mechanical considerations which control it and the diversity of site conditions which may be encountered.

Design and ultimate costs are very dependent upon the assumed external loads due to wind, and ice where this occurs, and the additional protective measures in severe lightning regions. In service all material, particularly that under electrical stress, must satisfactorily withstand the effects of corrosion and atmospheric contamination. On this aspect, modern developments in new materials and processes will undoubtedly be used to the fullest extent.

Although there are fifty years of experience available there are still outstanding electrical and structural problems, further study of which should contribute to more efficient operation and overall economies.

Direct-current high-voltage transmission has become a practical reality and may in the future be extended in scope when conversion equipment becomes fully developed and economic. Dc overhead transmission line costs are basically 30–40 per cent cheaper than with equivalent ac circuits and present no serious additional problems in either design or construction.

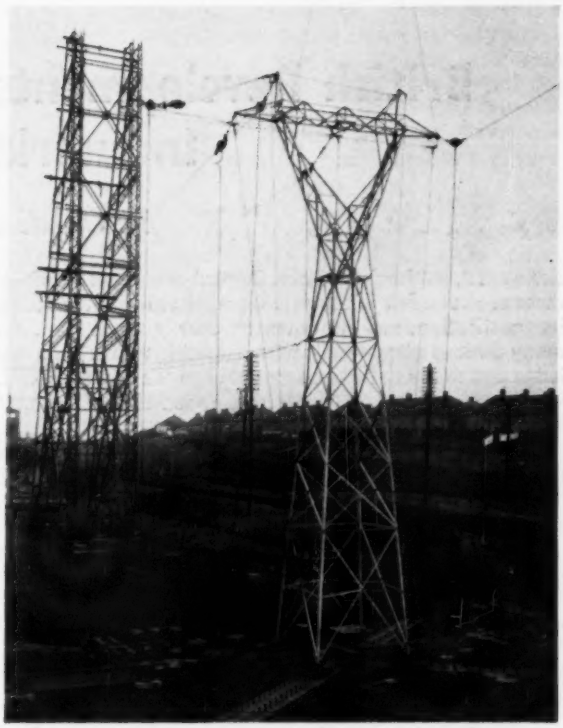


Fig 6. Single-circuit 66 kV lattice steel tower under mechanical test

Faraday House Engineering College

A NEW Board of Governors has recently been appointed by Faraday House Engineering College, London. The Chairman of the reconstituted Board is Colonel B. H. Leeson, Director of the British Electrical and Allied Manufacturers' Association.

Faraday House Engineering College came into being in 1889. It has been a pioneer in the field of technical training, and many years ago was the first to introduce the 'sandwich system' whereby students serve alternate periods in college and industry.

The College is fully alive to the need for expanding the number of well-trained technicians to support the work of the technologist in industry, and in shaping its future policy it may well give another important lead in this aspect of technical education.

The composition of the new Board of Governors is as follows:

Colonel B. H. Leeson, CBE, TD, MIEE (*Chairman*)
F. A. Bell, FCA (*Deputy Chairman*)
Sir Josiah Eccles, CBE, MM, DSc, MICE, MI Mech E, MIEE
Sir Vincent de Ferranti, MC (*President of the BEAMA*)
T. E. Goldup, CBE, MIEE (*President IEE*)
S. E. Goodall, MSc Eng, MIEE (*Vice-President IEE*)
J. O. Ince, Comp IEE
J. F. R. Ince, MIEE
Sir Frederick James, CBE
Sir Hamish MacLaren, KBE, CB, DFC (*Vice-President IEE*)
Dr Arthur D. Merriman, GC, OBE, DL, MA, DSc, CIE Mech E
Sir Gordon Radley, KCB, CBE, MIEE
L. W. Smith, BA

Ex Officio

President, Faraday House Old Students Association—T. A. D. Honnor, MIEE
Senior Vice-President, Faraday House Old Students Association—J. W. Bailey, MIEE
The Principal—G. H. Randolph Martin, HND, AMIEE, M Brit IRE, MI Mar E

British Developments in Nuclear Energy for Industrial Purposes

Sir Claude Gibb, KBE, FRS*

EINSTEIN, Rutherford, Bohr, Oppenheimer, Cockcroft—these are but a few of the names associated with the atom, its constitution, and its potential energy when split. So many nations played their part in adding to world knowledge and many nations contributed to the atomic bomb, which, exploded over Hiroshima, ended the Pacific war with dramatic suddenness.

The fact that the splitting of the atom was first applied for terrible destruction has surrounded fission with a fear of possible explosions even when the applications are entirely for the benefit and not the destruction of mankind.

The United States of America, with invaluable help from many British and other-nation scientists, produced the first atomic bombs, and in 1945 had accumulated a vast amount of knowledge which the highly controversial McCarran Act of the United States prevented from being placed at the disposal even of those nationals who had provided so much of it.

Britain in 1945 had a handful of scientists with considerable knowledge of certain facets of the atomic field, but without access to the accumulated information of so many fields of activity they could not proceed from the stage reached in 1945 and had to begin fundamental research almost from first principles.

The formation of the Atomic Energy Research Establishment at Harwell and of the Engineering and Production Division at Risley marked the beginnings of a remarkable—one might almost say amazing—period of development which is continuing to-day at an ever increasing rate.

Fig 1. A photograph of a model of the Bradwell nuclear power station

Harwell had as its prime object the widening of our boundaries of knowledge, and while much of its research was aimed at finding the answers to specific questions framed by the Production Division, a vast amount was research essentially to fill gaps in our knowledge without thought as to whether the results would have any practical application either for military or industrial uses.

Risley was charged with the application of the Harwell work, first for military purposes, as witness Windscale and Capenhurst, and later, jointly industrially and militarily as at Calder Hall.

Calder Hall had two purposes. It was first to be an efficient and cheap method of producing plutonium for military needs, but was also to demonstrate on a considerable scale that electricity generation could be carried out economically as the result of controlled nuclear fission.

The considerations leading to the selection of the moderator, coolant, and the general design features of Calder Hall were given to the world in a series of outstandingly valuable papers read before the British Nuclear Energy Conference in November 1956.

Construction of Calder Hall began in August 1953 and the station was officially opened in October 1956 by Her Majesty the Queen.

British industry cooperated in the design and construction of Calder Hall and has itself made extraordinary progress since then as the result of advanced researches and engineering developments. Although the Atomic Energy Authority initially selected four major consortia to be given the opportunity of staff training and access to design and operating experience, each consortium had of necessity to encourage a very wide field of industry to join with them before all the aspects in design and construction of a complete nuclear power station could be covered. In the case of the Bradwell nuclear station approximately one thousand firms are or will be engaged during its manufacture and construction.

Britain has had and still has an urgent need to develop nuclear power to supplement its dwindling coal reserves and its oil imports which, coming mainly from the Middle East, are under a constant threat from one or other source. To meet our needs at home requires large blocks of electrical power generated at a total cost competitive with that produced from coal-fired plants.

Four major purely industrial nuclear power stations are at present under construction in Great Britain and further sites for such stations are now being selected. All these sites will be remote from a major coal-producing centre mainly because the extensive mechanization of coal winning and loading is producing such a large proportion of small coal which is so unsuitable for domestic, railway, and many industrial uses that it is burnable only in large combustion chambers such as are found in modern large coal-fired electric power stations. Hence coal-fired power stations will need to be built close to coalfields provided that adequate cooling water and suitable sites can be found.

* Chairman and Managing Director, C. A. Parsons & Co Ltd.

The four nuclear power stations now under construction in Britain are expected to come into operation during 1960, 1961, and 1962. They will generate electricity at a cost only slightly above that produced by modern coal-fired stations.

The fact that there is no smoke or dust emission from a nuclear station means that a radical change in architectural design may be made. Fig 1 is reproduced from a photograph of a model of the Bradwell nuclear station now being constructed on the River Blackwater in Essex. The changes in appearance from an orthodox coal-fired power station are readily observed, but the differences are even more marked by the use of light-coloured cladding materials which are possible because of the inherent cleanliness of the nuclear station.

Fig. 2 is a photograph of the Bradwell site taken one year after the commencement of construction and shows the excellent progress being made. Similar progress is being made at the Berkeley nuclear station on the River Severn in Gloucestershire which began construction at the same time.

The four nuclear stations under construction will have a total net electrical capacity sent out of 1400 MW and a total cost, including the first fuel charge, of over £200 million sterling. No nation in the world could possibly contemplate a construction programme on such a vast scale unless it was certain of success both technically and economically. This programme alone should be convincing evidence to the world that Britain leads all other nations in the peaceful application of nuclear energy.

These four stations are all developments of Calder Hall, and the great advances on Calder Hall which they incorporate are due to the researches and engineering skill of British industry who are backing their faith in that skill by contracting to construct those stations under quite normal commercial contract conditions.

Hunterston in Scotland, Berkeley, and Bradwell have outputs approaching four times that of Calder Hall. Hinkley Point in Somerset will be some six times greater than Calder Hall in output, and that is by no means the limit in the light of most recent developments. There appears to be no reason why outputs of ten times Calder Hall per reactor could not be built to-day. A two-reactor nuclear station with an output of 1000 MW could be built with certainty and safety equal to those currently being constructed.

The four British nuclear power stations are of the natural uranium graphite-moderated gas-cooled type, and as such are free from the possibility of fuel not being available should international tension increase and enriched uranium be commandeered for military needs.

Enriched uranium as a fuel has certain important advantages. It enables a reactor for a given output to be built at a lower capital cost than one using natural uranium. But the fuel costs are of course increased and the final costs of a unit of electricity available for sale are unchanged if the station can operate at a load factor of 75 per cent or greater. It is for stations which must operate at a relatively low load factor that enriched uranium as the fuel has considerable advantages. It is a simple matter of economics that to obtain the lowest cost per unit of electricity, a high capital, low fuel cost station must operate at a high load factor so that the high capital costs are spread over the largest possible number of units sold. Conversely, a high fuel cost but low capital cost station is most suitable for low load factor operation.

In Britain to-day, where the annual system load factor is below 50 per cent, there is great scope for tariff modifications to encourage off-peak usage of electricity and so to build load factor, particularly during winter where the ratio of peak demand to minimum load is greatest. Again, this is to spread transmission and distribution capital costs over the largest possible number of units and to minimize the number of generating sets which must be shut down each night.

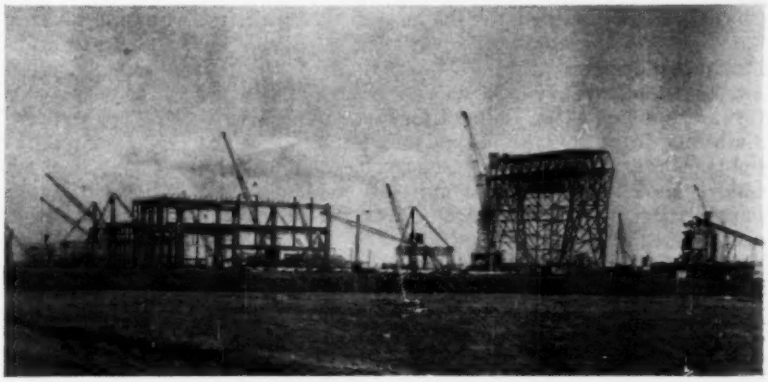


Fig 2. Progress in one year from the beginning of work on the Bradwell site

At present, we have sufficient plant in Britain to meet peak demands from relatively old, relatively inefficient, and therefore high fuel cost sets, which have been greatly depreciated or even completely written off and therefore carry low capital charges.

By 1965 there still will be such a small proportion of nuclear plant in Britain that it can be used for base load generation with maximum economy. But by 1970 there will be more nuclear power generating capacity than the likely minimum base load at that time and hence future designs of nuclear plants must be capable of operating at load factors well below 75 per cent with good economy.

This will call for considerable reductions in capital costs and some changes in present designs. But it also means that the graphite-moderated gas-cooled reactors will almost certainly go on being developed and constructed for probably ten years.

Improvements will be in two main directions. It will be obvious that, as the diameter and height of a reactor core are increased, fuel elements at the core periphery where neutron escape must be a maximum, will become a smaller proportion of the total fuel, and thus neutron economy and pile reactivity are improved. This rate of improvement is considerable and, other design features remaining constant, is the biggest factor in reducing capital cost and increasing fuel burn up. The other direction of improvement is in heat transfer both in the reactor itself and in the heat exchangers (or boilers as they now are coming to be called). Fuel can configuration affords considerable scope for research and development

and a great deal of rewarding work has already been done on this. To increase heat transfer without increasing pressure drop or adversely affecting neutron economy, introduces problems of great complexity which can only be solved by painstaking experimental work on a large and costly scale.

In the boilers, heat transfer must be considered as a matter of economics. Extended surface tubes materially improve heat transfer per foot length of tube but, of course, at considerable extra cost per foot. Extended surface tubes would reduce the overall dimensions of the containing boiler shells or may even reduce the number of boilers. The extended surface may be provided by fins rolled integral with the tube wall or by continuous fins or aerofoil shaped studs welded to the tube. Only by laborious estimating of the costs of alternative designs can the designer decide upon the most attractive design.

Future developments

Sir John Cockcroft in a recent article has outlined the forward thinking of the United Kingdom Atomic Energy Authority on future types of reactors. Sir John pointed out that the heat rating of fuel elements has doubled from Calder Hall to the stations currently building. This improvement by a factor of two has come from research carried out by British industry.

Similarly, it is due to experience and further research in industry that the basic thickness of the reactor pressure vessel has been increased from two inches (50·8 mm) at Calder Hall to three inches (76·2 mm) in the reactors currently building. This has allowed gas pressures to be increased with resulting improvements in heat transfer and lower auxiliary losses in gas-pumping power.

British industry solved the formidable problems in the design and construction of spherical reactor pressure vessels which the large output of industrial reactors demanded.

Sir John Cockcroft has drawn attention to one of the disadvantages of using uranium metal as the fuel. At 600 deg C uranium metal loses strength and at 650 deg C undergoes a structural change accompanied by an increase in volume. The necessity to avoid these difficulties imposes a limitation on allowable temperature and thereby on gas temperature, and this in turn limits steam pressures and temperatures and thus steam cycle efficiency.

Uranium oxide does not melt until a temperature of 2850 deg C is reached, and results of irradiation tests on this material at Chalk River, Canada, are most encouraging. Work on uranium oxide is proceeding at many laboratories in Britain, and in the near future can be expected to open up further avenues of development. None of these is likely to be spectacular, but they will lead to lower capital costs and improved fuel utilization.

One apparently attractive reactor is the liquid sodium or sodium potassium cooled graphite-moderated type. Liquid metal as the coolant has great advantages, but, as is so often found in engineering, there are also many disadvantages. Liquid sodium introduces severe problems, not the least being those of compatibility between coolant and fuel element can, and between coolant and graphite moderator. Sir John Cockcroft doubts whether liquid metal cooled reactors will have economic advantages sufficient to make the solving of the many severe engineering problems worth while. Engineers who have studied the liquid sodium cooled reactor shudder at the problems involved and return with relief to the gas-cooled reactor.

Fig 3 shows a section through a typical gas-cooled graphite-moderated reactor such as is being built to-day. Advances as the result of further researches in the past two years have enabled an output increase of over one-third to be obtained from the same weight of uranium as fuel and graphite as moderator. Development work now in hand appears to offer still further increases.

Within ten years—probably less—we can be certain that one ton of uranium will produce as much electricity as 50,000 tons of coal. Within twenty years, and as the result of the successful development of the fast breeder reactor, we can expect to make one ton of uranium do the work of one million tons of coal. This is the forecast of Sir John Cockcroft and British reactor designers fully support it.

British nuclear engineering development has almost entirely been directed towards the production of large power stations optimized for the generation of electricity. Thus the well-established and universally accepted criteria for such stations have been applied at all stages of design. These are:

(1) Safety and maximum reliability to take priority in all considerations.
(2) Minimum cost per unit of electricity produced available for sale.
(3) Minimum nuisance during construction and operation, and least possible objection aesthetically.

Inherent in (1) and (2) are reasonable simplicity in operation and maintenance.

It may well be that the maximum possible efficiency of fuel utilization, or even the lowest capital cost plant, is unacceptable because of operating complications, and inevitably engineering considerations must prevail in making the final decisions.

Sixteen Types of Reactor

Dr J. V. Dunworth, the Head of the Reactor Division at Harwell, has shown that there are at least sixteen basic types of reactors from which to choose. Each of these possible basic types have been considered and studied both for nuclear and engineering advantages and disadvantages.

Canadian nuclear effort was originally directed to the heavy water cooled and moderated type. Detailed engineering study showed this to have grave objections, and work now is proceeding on a heavy water moderated but gas-cooled reactor. Much attention is being given to this type of reactor in Britain at present, but it is not thought to have the potential advantages of the graphite-moderated gas-cooled reactor.

The major developments in the United States of America have been in the light water moderated and cooled type and notable examples are the submarine *Nautilus* and the nuclear power station at Shippingport. Both have been satisfactory technically but are believed not to be so economically. Light water moderated reactors demand enriched fuel which is not necessary for graphite or heavy water moderated types. On the evidence available to-day, it is unlikely that a light water moderated and cooled nuclear station could compete with a gas-cooled graphite-moderated one.

A disadvantage of heavy water as the moderator is its cost, while the high gas pressures necessary for reasonable heat transfer introduce considerable on-load refuelling

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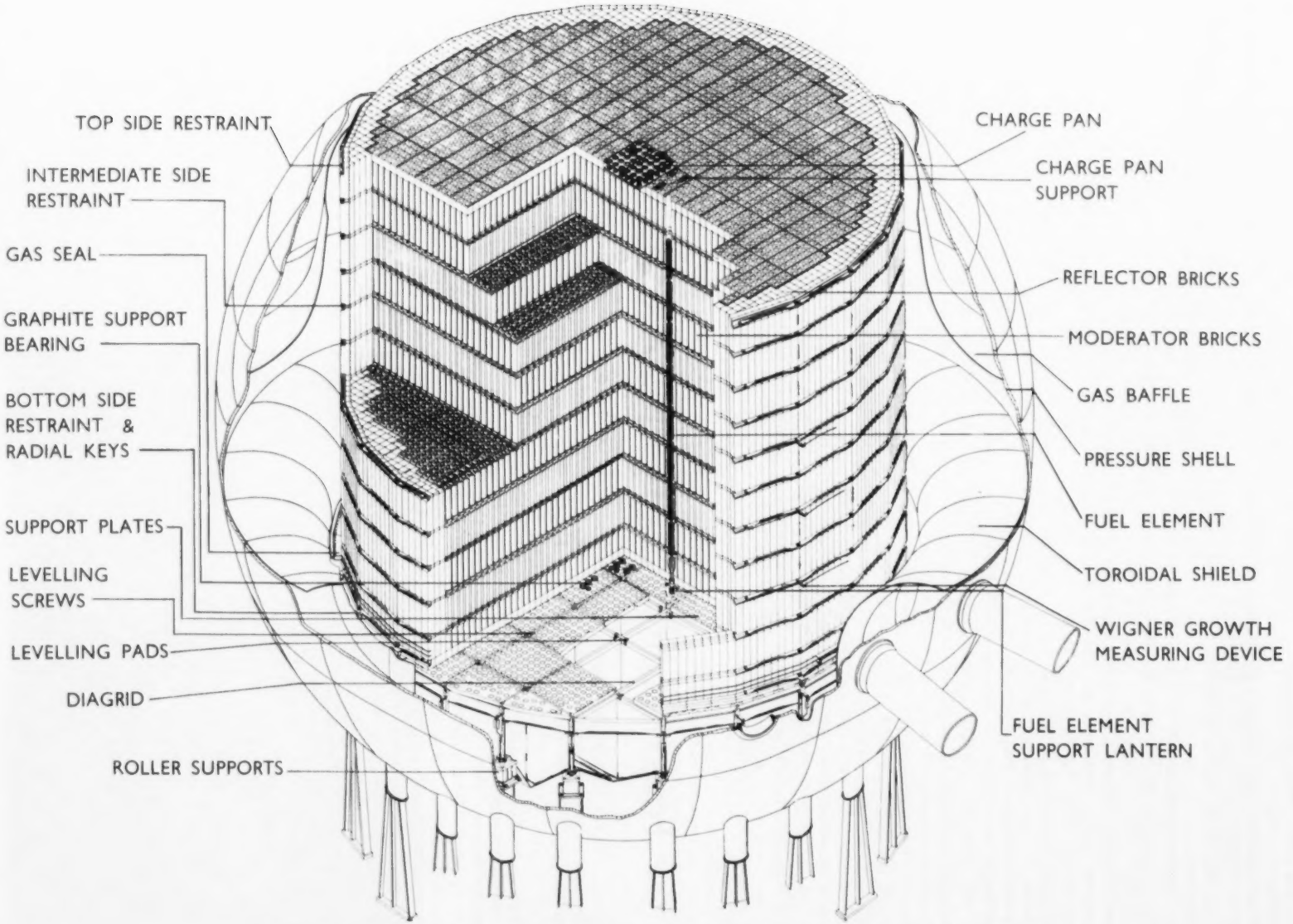


Fig 3. Section through a graphite-moderated gas-cooled reactor typical of current British technique

difficulties. Nevertheless it has attractions for ship propulsion and, after much development, for large nuclear stations.

An alternative to light water is one of the hydrocarbons such as diphenyl or terphenyl. Studies of this type of reactor are being made in Britain for rather special applications.

At Dounreay in Scotland, the United Kingdom Atomic Energy Authority are approaching the completion of a fast breeder reactor which, as a long-term project, has tremendous possibilities. Great credit should be given to the Atomic Energy Authority, not only for their courage in proceeding with the Dounreay project, but for the engineering skill which has been shown in designing such a difficult and complex piece of engineering.

Correctly designed, a fast breeder reactor can produce more fissile material than is consumed. This, however, does not mean that perpetual motion is now with us. Metallurgical damage of the breeder fuel elements occurs long before complete or even a high burn up has been achieved. This necessitates chemical processing of the fuel, and the extent and cost of this may possibly make the breeder reactor less attractive than it at first appeared.

Britain may have been fortunate that the availability of reactor materials exercised a considerable influence in choosing the graphite-moderated gas-cooled reactor as that to be developed. Certainly no other type so admirably fitted Britain's need. But we have been even more fortunate in having had the brilliance and courage of Hinton, Owen, Moore, Cunningham, and their colleagues who developed the engineering designs from the basic researches of Harwell.

Finally, what of fusion? Will the undoubted lead which Britain holds in the world of fusion to-day be maintained and found capable of producing electricity competitively in the reasonably near future? However attractive fusion may seem, the engineering difficulties must not be underestimated. There is no reason to doubt the ability of the physicist to produce temperatures of one hundred million degrees or more. Such temperatures do not frighten the engineer. There is no clear picture as yet of the mechanism whereby the electromagnetic phenomenon discovered by Faraday can be replaced for the large-scale production of electrical energy. It will demand long and painstaking study and development. No engineer will forecast whether fusion will have an impact in ten, twenty, or fifty years, or in fact ever. But the engineer will be ready to take over from the physicist the moment the basic problems have been even partially solved.

Britain has every right to be proud of the part it has played in the development of nuclear energy for industrial purposes and is looking forward to collaboration with other nations in the construction of nuclear power stations in many parts of the world.

Fourth Edition of the BEAMA Catalogue

TIMED to coincide with the opening of the 1958 Brussels Exhibition and to link up with the British Electrical and Allied Industry's exhibit, the publication of the Fourth Edition of the well-known BEAMA Catalogue was marked by an informal ceremony in London when the first copy of the new edition was presented to Mr John K. Vaughan-Morgan, MP, Minister of State, Board of Trade, by Mr J. O. Knowles, Chairman of the Council of the British Electrical and Allied Manufacturers' Association.

In the course of his speech, Mr Knowles referred to the more than 1300 headings in the Buyers' Guide section of the Catalogue, under which are specified products manufactured by BEAMA members. Bearing in mind that this Catalogue is intended for world-wide distribution to cover 100 territories, the 1300 product headings are listed in English, French, German, Portuguese, and Spanish, separate alphabetical lists being also given in each of these languages.

He also pointed out that this comprehensive Buyers' Guide and Trade Directory occupies only a minor part of this Catalogue. The particular distinction of the BEAMA Export Catalogue lies in the unique arrangement of the 700 pages which are descriptive of BEAMA firms. The idea of these pages, he said, is to report upon each firm as if the distant reader of this book had had the opportunity of visiting in person the works and offices of that firm.

This Catalogue, he said, is a cooperative effort by members of our Association, working together for the good of all of us in export market.

Accepting his copy of the Catalogue, Mr Vaughan-Morgan welcomed the opportunity of drawing attention publicly to the great contribution the electrical industry is making in the field of exports. He congratulated the Association on the valuable and attractive form of publicity provided by the Catalogue, and especially on the new feature of the three supplementary catalogues which should increase its value to users and to visitors to the Industry's exhibit at the Brussels Exhibition.

He concluded in these words: 'We in this country are too ready to underestimate, even to ourselves, the value of our achievements. Modesty is an excellent personal virtue, but in international trade in a fiercely competitive world, it may be mistaken for lack of confidence. Customers are becoming conditioned, through the flood of present-day advertisement methods, to think only of goods of whose perfections they are constantly reminded. This Catalogue is one method of reminding past customers and attracting the attention of new ones to what United Kingdom industry can offer.'

Fifteen thousand copies of the main 962-page Catalogue have been distributed free to selected buyers all over the world, and additional copies have been made available at Brussels for potential customers. Sixteen thousand copies of the three supplementary sections—each comprising one of the following divisions of the main Catalogue: Generation and Transmission; Industry, Transport and Communications; Domestic and Commercial equipment—have also been issued.

The 1958 edition contains much information about nuclear engineering—a development which has come very much to the fore since the third edition in 1955.

Notes

Hotel and Catering Exhibition

The many ways in which electricity can so efficiently serve the hotel and catering industry were well shown at the International Hotel and Catering Exhibition held recently in London.

The British Electrical Development Association, with the cooperation and support of the Commercial Electrical Catering Section of BEAMA, ensured that all the manifold advantages of electricity to the industry were well displayed and explained. Strong emphasis was placed on the necessity for hygiene in all places where food is prepared, cooked, and served, and to achieve the required high standards it is essential to provide adequate lighting, good ventilation, an ample supply of hot water, and efficient cleaning appliances. Electricity is the only medium that can provide *all* these requirements, as well as the means for preparing, cooking, and storing food.

Equipment and appliances covering every aspect of small- and large-scale catering were displayed and demonstrated on the many stands of BEAMA members, as well as on the large exhibit staged by the British Electrical Development Association. The Association also arranged a conference and a film show, and the electrical equipment—which included two chef ranges, a boiling table, and a refrigerator—in the demonstration theatre. Here are brief descriptions of the EDA and BEAMA members' stands.

The impressive and well-laid-out EDA exhibit was divided into three main sections: a canteen kitchen equipped with every electrical appliance required for catering for 250 people; a smaller all-electric kitchen suitable for a small restaurant serving 60 to 65 customers; and a snack bar. Ample supplies of hot water for washing-up and so on were provided by electric water heaters, with separate wash units and electric hand driers for staff use. Proper ventilation was ensured by fans and air extractors, and electrically vaporized insecticide kept the air clear of flies and other insects.

The *Carron Company's* exhibit included a range of heavy-duty equipment, such as grillers, fish friers, and a double oven range.

Chilton Electric Products Ltd featured two principal items: the Mark II shaver socket, accommodating all British and overseas voltages and plugs, and double wound, with an earthed screen between primary and secondary windings; and their compact spin drier.

Floor-cleaning machines in a range of medium and heavy duty power-operated types were shown by *Columbus Dixon Ltd.* They are obtainable as either combined or single purpose machines for floor scrubbing and drying, power floor scraping, floor dry cleaning, polishing, surfacing, floor polish spraying, and carpet shampooing.

The principal feature of the stand of *Crypto Ltd* was their large range of food-preparation equipment: potato peelers, automatic chip cutters, coffee mills, mincers and bowl cutters, slicers and mixers with multi-purpose attachments. They also showed steam cookers and hand and face driers.

An exceptionally wide range of counter-type equipment suitable for large or small establishments was shown by *Electroway Heaters Ltd*, including a new griddle grill exhibited for the first time. Other products on the stand included such items as hot cupboards, napkin dispensers, salamanders, hotel fires and convectors.

The display of general catering equipment by *Euk Catering Machinery Ltd* consisted of service counters incorporating hot closets, bains marie, a new refrigerator drawer unit, and cold sections. Demonstrations were given of dish-washing and butter-spreading machines.

The Falkirk Iron Co Ltd showed heavy-duty cooking equipment, together with countering and sink units. Of particular interest was the firm's moving-belt set-up table designed for Bermuda Aviation Services Ltd for use at Kindley Field Airport. With this equipment it is possible to lay up 8 to 10 aircraft meal trays a minute, with up to 18 pieces on each tray.

The large stand of *Gardiner and Gulland Ltd* was laid out with a complete cafeteria service counter with back bar, embodying the latest equipment for food warming, sandwich preparing, and so on, and a new type of infra-red overhead heated chip scuttle. A complete snack bar was also featured.

The General Electric Co Ltd had a comprehensive display of electric cooking equipment, including a single oven range that can be built up in multiples. New items of interest were a 15 cu ft (0·4 cu m) commercial type refrigerator; a rapid ice maker for hotel bars; a griddle plate which will deal with 400 hamburgers an hour or 12 chops every 10 minutes, and an air conditioner which works on the heat pump principle. Also on view were the Osram tubular infra-red quartz heat lamps described in the last issue of THE BEAMA JOURNAL.

Hoover Ltd were, of course, showing their famous range of cleaners, washing machines, polishers, and irons. For hotel use, the Hoover heavy-duty cleaner was featured as the most suitable.

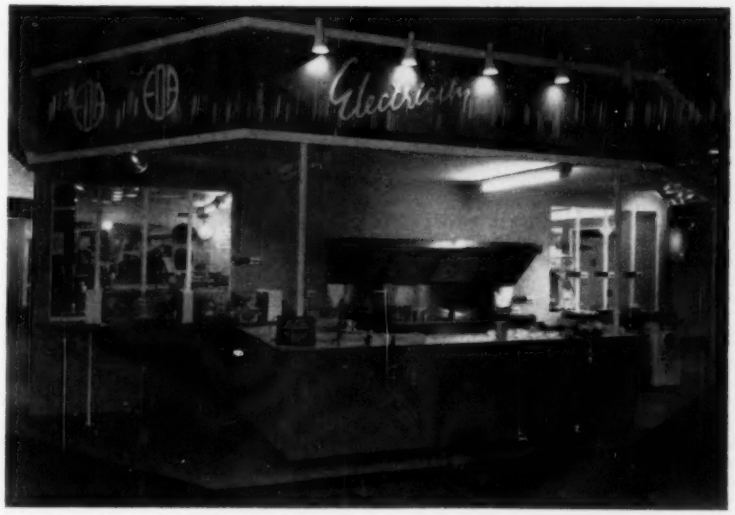
A wide range of cooking equipment by the *Jackson Electric Stove Co Ltd* covered the requirements of large and small hotels, restaurants, schools, hospitals, and industrial canteens. It included a new pastry oven available in one, two, or three tiers and with heating elements located at the top, bottom, and sides to give quick and even cooking in each oven. The stand also included a selection of convector heaters, adjustable and panel fires, and water heaters.

The Kenwood 'Major', shown by the *Kenwood Manufacturing Co Ltd*, is a versatile food preparation machine with a great variety of attachments and a 6 quart (6·8 l) stainless-steel bowl. Other equipment on this stand included the Kenwood 'Rotisserie'—an infra-red cooker for counter use; a spin drier, and a fan convector heater with a choice of 9 heat and fan settings.

A new rotary continuous toaster with a capacity of 500 slices an hour, and a stainless steel bain marie with thermostatic control were featured by *Simplex Electric Co Ltd*, together with a selection of standard Creda equipment consisting of heavy-duty chef and unit ranges; a light-duty restaurant range, salamanders, hot cupboards, and water boilers.

On their large stand, *James Stott & Co (Engrs) Ltd* ('Stotts of Oldham') introduced several new items, notably a range of inexpensive water boilers with outputs of 120, 240, and 360 pints (68, 136, and 204 l) an hour; a range of stainless-steel water-boiling urns, and an espresso-type coffee unit. Another item of interest was the 20 ft (6·1 m) service counter incorporating the latest trends in food service.

A new small-size rotary sausage grill by *Taylor Electrical Instruments Ltd* measures only 22 in long by 13 in wide by 7 in high (56 cm by 33 cm by 18 cm), yet is capable of cooking 30-35 sausages in 10 minutes. The sausages lie on a series of slowly rotating rollers, each of which houses an electric heating element controlled by a simmerstat. The rotary action cooks the sausages evenly all over without burning, and they need no watching or manual turning.



A view of part of the EDA stand at the Hotel and Catering Exhibition

Group apprentice training for smaller firms

The training of future craftsmen for industry is given particular prominence in the report 'Training for Skill' recently issued by the Carr Committee. The report stresses the need for increased and more widespread facilities for practical training, which means that training should be undertaken by the smaller firms as well as by the large organizations.

What the latter have done for many years through their varied and comprehensive courses can be similarly undertaken by small and specialized firms by means of Group Apprenticeship Schemes, and these facilities already exist in the engineering industry through EIAGA—the Engineering Industries Association Group Apprenticeship—which has been in operation since 1954.

A great deal of importance is placed on the selection of the right type of boy for each grade of apprenticeship. The group supervisor, therefore, works closely with the Youth Employment Service, parents, and schoolmasters, and submits suitable candidates to member-firms, with whom the final decision rests.

Once accepted, the boy starts work with his parent firm as a probationer, following the practical and theoretical syllabus appropriate to his grade. On completion of his probation period, he is indentured to his parent firm from his 16th birthday, or the date of his enrolment, if later.

In arranging technical college instruction for EIAGA apprentices, care is taken to ensure that each boy enrols for a day-release course which is within his ability and appropriate to the grade and trade in which he wishes to qualify. The possible advantages of block as opposed to day-release courses are being investigated, and EIAGA craft apprentices will attend a block-course which is to be run experimentally by one Technical College, starting in September 1958.

The aim of EIAGA can be summarized as that of giving its apprentices a broader and more detailed training than has hitherto been possible in the small and specialist firm.

EIAGA groups are at present established in the Greater London Area, the Midlands, and the North-West. New groups will be formed in any district where local industry wishes to participate.

Largest post-war order from Poland

The largest single order placed by Poland in Great Britain since the war was recently announced by Metropolitan-Vickers Electrical Co Ltd.

Worth £2½m, the contract is for two 120-MW steam turbine alternators for installation in a new power station in the Donbrova district, not far from Katowice and reasonably adjacent to the coalfields of Upper Silesia.

The order was placed by 'Elektrim' (the official Polish organization dealing with the import and export of electrical equipment) with the agreement of the Board of Trade. It is understood that Metropolitan-Vickers secured the contract in the face of keen competition from European countries—an achievement which reflects the greatest credit on the firm and on the British electrical industry.

The contract was welcomed by Dr A. Wolynski, Commercial Counsellor at the Polish Embassy in London, who foreshadowed the placing of further orders with the British electrical industry if favourable conditions for a two-way interchange of trade enable Poland to increase her exports to this country as a means of financing future business on these lines.

The two steam turbines, which in themselves are the largest ever ordered from Britain for use in Europe, will be of the 3-cylinder (126·5 kg/cm²) reheat type running at 3000 rpm, with steam conditions of 1800 lb/in² (56·2 kg/cm²) and steam temperatures of 1000/1000 deg F (537·8 deg C). They will be direct-coupled to alternators rated at 120 MW, 0·8 pf, 13·8 kV, 3 phase, 50 cycles. They will be hydrogen-cooled, using hydrogen at a pressure of 30 lb/in² (2 kg/cm²).

'Porcelain Insulators in the Making'

Porcelain insulators, among the most widely used auxiliaries of the electrical industry, are nowadays produced on a considerable scale by various machine processes. *Doulton Industrial Porcelains Ltd*, who recently showed a film entitled *Porcelain Insulators in the Making*, manufacture insulators in 1200 different patterns which fall into six categories—those for overhead distribution and power lines; those for switchgear and transformer manufacturers; heavy-duty post insulators for busbar support and substation switchgear; railway insulators for both third rail and overhead catenary systems; those for ship's radio installations; and mast base and rigging insulators for broadcasting towers.

Dipping a completed insulator in the glaze.
(A shot from the Doulton film)

The film showed clearly how much care has to be taken in the selection of materials involved in the preparation of heavy-duty ceramic products. Quartz, felspar, ball clay, and china clay are prepared under strict laboratory control and blended in accurately determined proportions. The film then described how the mixture or 'slip' is passed through fine-mesh sieves and over electromagnets to remove metallic impurities before it flows into tanks where it is kept in continuous circulation. Filter presses remove surplus water and leave sheets of clay which, in the final stage of preparation, are passed through a pug-mill to extract all air under high vacuum and to give a completely uniform mix. The clay is finally extruded in cylindrical form and cut into the varied lengths required.

In general, the clay cylinders are shaped into insulators on the jolley or on specially designed lathes, with moulds and metal profiles taking the place of the potter's hands. After this comes the glazing, where again the raw materials of the glaze and the proportions in which they are mixed are of vital importance in ensuring that the thermal expansion of the glaze corresponds exactly with that of the insulator body.

After manufacture, the insulator goes through the most stringent tests before it is put into service. Routine and sample tests are carried out to British Standards and to the American NEMA standards. A further manufacturing process often follows these routine electrical checks. An insulator may be machine ground to an accuracy of plus or minus one sixty-fourth of an inch (0·4 mm). One of the essential requirements is, of course, that the insulator should be non-porous. Each individual section of porcelain is immersed for twenty-four hours in a 0·5 per cent alcohol solution of fuchsin and kept under a pressure of 2000 lb per square inch (141 kg/cm²). The pieces of porcelain are then removed and broken to ensure that there is no sign whatsoever of any dye penetration.

Copies of the film are available on loan from Doulton Industrial Porcelains Ltd, Doulton House, Albert Embankment, London, SE1.

Canadian sectional meeting of World Power Conference

Scheduled to be held in Montreal from 7 to 11 September 1958, the theme of the Canadian Sectional Meeting of the World Power Conference will be 'Economic Trends in the Production, Transportation and Utilization of Fuel and Energy'.

This theme will be considered under its three main divisions: Production, Transportation, and Utilization, and technical sessions conducted in French and English have been arranged to discuss the paper submitted. Wherever possible, a complete set of pre-prints of technical papers will be mailed to each registered participant in time to afford an opportunity for study before the meeting. These pre-prints will be issued in the official language in which the paper is submitted, with a summary in both official languages, and accompanied by a general report in both official languages. Details of the procedure at the technical sessions are given in the official handbook.

Copies of the general programme can now be obtained from the Secretary, British National Committee of the World Power Conference, 201-2 Grand Buildings, Trafalgar Square, London, WC2, through whom all applications to participate in the Conference must be submitted.

Completed application forms must be in the hands of the British National Committee in time for them to reach the Canadian secretariat not later than 1 July 1958.

[Continued on page 91

Postgraduate course in nuclear power for design engineers

Prof J. M. Kay, MA, PhD, MIMechE, AMIChemE*

It was realized at an early stage that the successful launching of the first large-scale nuclear power programme in the United Kingdom would depend entirely on the close cooperation of the electrical manufacturing industry with the Industrial Group of the Atomic Energy Authority. To this end four large industrial consortia were formed to prepare designs for complete nuclear power stations. The major heavy electrical manufacturing firms undertook the task of acting as the focal points in these consortia. During the last three years each of the four original groups has built up a large and well-balanced engineering design team supported by massive research, development, and manufacturing resources, and each group is now actively engaged on the construction of one of the first four commercial power stations in the United Kingdom.

The Problem of Training

The characteristic requirement of nuclear power station engineering is the importance of the rôle of the design engineer. It has been found by experience that it is necessary, in order to design and construct a large project such as a nuclear power station, to have a coordinated team of civil, mechanical, and electrical engineers in charge of the work. Because of the rapid pace of scientific and engineering development, the design and construction team must be supported by a corresponding research and development team comprising metallurgists, physicists, chemical engineers, and other applied scientists. The important point to note is that all these engineers and scientists, while working in the field of nuclear power, will retain their allegiance to the particular branch of engineering or applied science in which they are professionally qualified.

With these considerations in mind, the postgraduate course at Imperial College has been planned primarily to meet the needs of graduates in mechanical, civil, electrical, and chemical engineering who wish to enter the field of nuclear power and technology. The course is also open, however, to applied scientists—particularly physicists and metallurgists—who are interested in the research and development field associated with nuclear reactors and nuclear processes.

A special feature of the present course is the inclusion of a design study of a complete nuclear power station or related process engineering project. This design study, which extends over the whole year, is used to illustrate the way in which the various basic branches of engineering and applied science must be integrated in relation to the needs of an actual constructional project. Each student is given a particular part of the design to carry out in detail during the year and the choice of individual tasks is related to the student's particular interests and background. Special lectures and discussions are held regularly to progress the work of the design study. Visits to appropriate engineering works and constructional sites are also arranged during the year. The design study will be of particular value to men who wish ultimately to become first-class design engineers either in nuclear power or in process engineering. It will also be of value to applied scientists whose work in the field of research and development must be related to the requirements of a constructional programme.

Although presented from the engineering point of view, and with great emphasis on the preliminary training of design engineers, the present course at Imperial College does not neglect the important subject of reactor physics. Both the basic ideas of nuclear physics and also the specific applications to reactor core design are dealt with at considerable length. Special importance is attached to the experimental basis of this subject and a large subcritical natural uranium graphite exponential assembly has been constructed at Imperial College for demonstration and research purposes. Other important experimental projects associated with the course include a large heat transfer rig for the basic study of heat transfer between fuel element surfaces and the coolant gas, and a comprehensive analogue computer for the study of transient conditions in reactor systems.

The general aim of the course is to provide postgraduate engineering training at advanced level. For this reason the number of places was limited in the first year to twenty-five. From the 1958–59 session onwards, however, it is hoped that it may be possible to provide facilities for a total number of between thirty-five and forty postgraduate students.

Close cooperation is maintained with the UK Atomic Energy Authority, the Central Electricity Generating Board, and the principal industrial groups. In certain cases lecture courses on special subjects are being given jointly by members of the engineering staff of some of the leading industrial firms in association with the permanent lecturing staff of the nuclear power group at Imperial College.

Editor's Note

Details and syllabus of the course described by Professor Kay are contained in a newly issued booklet obtainable from the Registrar, Imperial College, London, SW7, to whom applications for admission to the course should also be made as soon as possible, but in any case not later than 1 July next. The course, which is a full-time one, lasts for one year; the fee is £64 (subject to revision), and qualifies for the award of the Diploma of the Imperial College (DIC).

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Controlling the fusion reaction

THE SIGNIFICANCE OF ZETA AND SCEPTRE

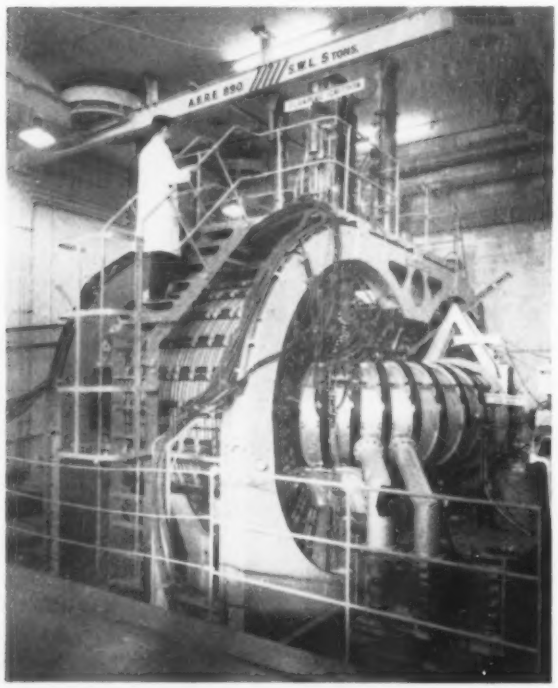
THE achievement of temperatures of the order of 5 million deg C for a sufficient time for fusion reactions to be produced in deuterium gas has been justly acclaimed as a triumph for British scientists and an outstanding landmark on the road towards the goal of unlimited atomic power for peaceful uses.

Atomic or nuclear power can be produced by two kinds of nuclear reaction—the fission (or splitting) of atoms, as at Calder Hall and the four new atomic power stations now under construction in Britain, and the fusion or thermo-nuclear reaction in which energy is produced by bringing about the fusion of the nuclei of hydrogen, the lightest element.

Twenty-five years ago, Sir John Cockcroft and his co-workers in the Cavendish Laboratory at Cambridge University discovered that nuclei of heavy hydrogen speeded up by a high voltage could fuse with other nuclei of heavy hydrogen to form helium of mass three, producing neutrons and energy in the process.

It is known that reactions of this kind provide the energy and heat of the stars. The sun, for example, has a central temperature of about 15 million deg C, and at this temperature the fusion of light hydrogen nuclei takes place and gives off enormous amounts of energy.

The fusion of light hydrogen in the sun, however, requires a cycle taking millions of years, but the physical conditions on earth demand that the reaction must take place in a matter of seconds. Accordingly, the scientists have turned to heavy hydrogen: deuterium with an atomic mass double that of light hydrogen, and tritium with an atomic mass three times that of light hydrogen.



The main Zeta assembly at Harwell

Deuterium is present in large quantities in sea water and can be extracted comparatively cheaply; tritium does not exist naturally but can be made from the light element lithium.

The objective of Stage 1 was therefore to produce temperatures of some 5 million deg for a sufficient time for fusion reactions to be produced in deuterium gas at low pressure. This has been achieved with Zeta at Harwell and Sceptre III at the AEI Research Station at Aldermaston. Temperatures of this order have been produced in Zeta for periods up to 5 milliseconds, and these have been repeated at intervals of 10 seconds for many thousands of times.

During these reactions, neutrons have been produced. When the temperature in Zeta reached 2 million deg a few neutrons were observed, and these increased 300 times as temperatures of 5 million deg were approached, until about a million neutrons are produced during each pulse. This, say the scientists, is what they would expect from heavy hydrogen nuclei moving with the random motion corresponding to these temperatures. The neutrons are produced in about the right numbers, and they increase at about the right rate for the increase in temperature. Nevertheless, it cannot yet be said to be definitely established that they are true thermo-nuclear reactions, since it is known that the nuclei could be speeded up by other mechanisms than being part of a hot gas.

Further investigations to prove beyond doubt the source of the observed neutrons are now being undertaken at Harwell, in the course of which it is intended to increase the current in Zeta and thereby substantially raise the temperature. If, and when, temperatures of the order of 25 million deg are reached, the number of neutrons per pulse should increase at least 10,000 times. Even then, the amount of energy produced would be small compared with the energy input.

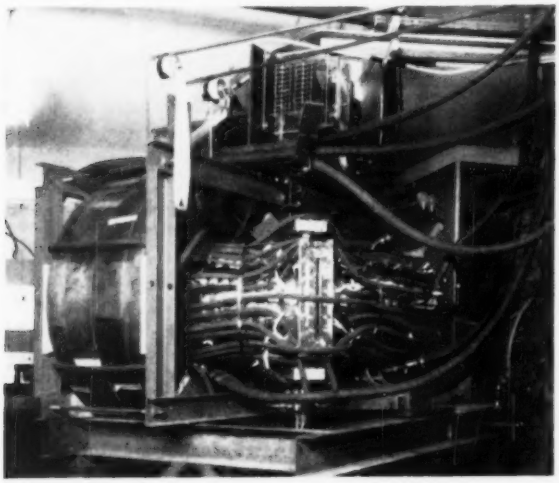
To reach the 'break even' point (Stage 2) it is forecast that temperatures of about 300 million deg in deuterium gas and about 40 million deg in a mixture of deuterium and tritium will be required. That raises many severe engineering problems, both electrical and physical; even when they are successfully surmounted, there will be further problems in Stage 3—the design and construction of the prototype of a practical and economic thermo-nuclear power station. Only then can Stage 4 be undertaken—the commercial application of thermo-nuclear power.

Zeta and Sceptre: their Principles and Construction

The basic conditions required to bring about a thermo-nuclear reaction are (*a*) that enough energy must be imparted to the deuterons to overcome the initial electrical forces of repulsion between them—which means heating the deuterium gas to several million deg C, and (*b*) that the hot gas must be kept away from the walls of

the container to avoid energy losses in the gas and the vaporization of the container itself.

The principle adopted in Zeta and Sceptre is to heat the gas by passing a heavy electric current through it. This sets up an electric discharge in the gas and also produces an intense magnetic field surrounding the hot gas which in turn acts on the charged particles which carry the current. The direction of the force exerted is towards the centre of the gas discharge, and if the current



Sceptre III at Aldermaston, showing the primary windings around the torus. The discharge is observed through the slit in the centre of the picture

is sufficiently large, the force is sufficient to cause the gas column to constrict visibly—a manifestation of the well-known 'pinch effect'. The great advantage of this 'pinch' is that it draws the hot gas away from the walls of the containing tube for short periods of time. However, it was found that the constricted discharge rapidly developed instabilities and distortions, and instead of remaining straight in the centre of the tube, it developed kinks which grew in amplitude and touched the tube walls. This instability was aptly named 'wriggling' and caused serious heat losses.

Overcoming this 'wriggling' was one of the major problems, and it was ultimately found that it could be suppressed by the combination of an axial magnetic field parallel to the direction of the discharge current, and by the fields produced by eddy currents induced in the surrounding metal walls when the current channel changes its direction.

From these considerations, the present design of Zeta was developed.

The discharge chamber is a ring-shaped circular tube or 'torus' with a bore of 1 metre and a mean diameter of 3 metres, made of 1 in (2·54 cm) thick aluminium, and is encircled over part of its length by the iron core of a large pulse transformer. The torus contains gas at a low pressure—usually about 10^{-4} mm of mercury—which is made weakly conductive by a radio-frequency discharge. Thus the toroidal ionized gas plasma forms the secondary of the transformer, and is, in effect, a short-circuited turn.

A capacitor bank storing up to a maximum of 5×10^5 joules is discharged into the primary of the transformer and produces a unidirectional current pulse in the gas up to a maximum of 200,000 A. The current pulse lasts for about 4-5 m sec and is repeated every 10 secs. The steady axial magnetic field to suppress 'wriggling' of the plasma is generated by current-carrying coils wound on the torus; the field can be varied from zero to 400 gauss.

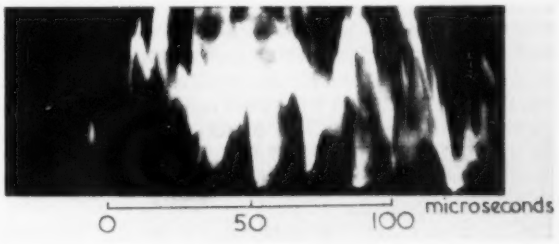
Measurements with magnetic feed probes and Langmuir probes, together with streak photographs of the current channel taken through a slit in the torus, show the current channel to be quasi-stable and clear of the walls for the greater part of the current pulse. Its estimated diameter is between 20 and 40 cm at peak current.

Gas temperatures have been measured by a vacuum spectrograph attached directly to the torus, using the Doppler broadening of spark lines for estimating the kinetic ion temperature of deuterium discharges, and it has been found that, with currents of the order of 180 kA, the temperatures calculated from the observed neutron yield have been in close agreement with the measured temperatures.

Similar results have been obtained by the scientists of the Associated Electrical Industries Research Laboratory at Aldermaston, working independently but in close collaboration with the team at Harwell.

The AEI apparatus is known as Sceptre III, and uses similar principles to those of Zeta but on a rather smaller scale. The torus is a ring-shaped aluminium tube of 12 in (304 mm) diameter, the mean torus or ring diameter being 45 in (1143 mm). It is threaded by an iron core weighing 4 tons, and is wrapped externally with many windings to provide the stabilizing axial magnetic field.

Very many experiments have been carried out with Sceptre, using electrical discharges of up to 40,000 joules giving currents up to 200,000 A in the deuterium gas. Temperatures of nearly 4 million deg C have been measured, and at temperatures over a range from 2·5 million deg upwards, the copious emission of neutrons for several hundred millionths of a second at a time have been observed.



Streak photograph of 80,000 A discharge in heavy hydrogen in Sceptre. The violent 'wriggling' before suppression is well shown

As at Harwell, experiments are being pressed on at Aldermaston to achieve still higher plasma temperatures and thus much greater neutron yields, the ultimate goal being always to produce a reaction energy greater than the energy input to the apparatus. But no one can yet answer the question of 'when?'

Much of the constructional work on Zeta was done by Metropolitan-Vickers Electrical Co Ltd, who also collaborated in the design. British Insulated Callender's Cables Ltd supplied the capacitors, Standard Telephones and Cables Ltd the rectifier equipment, and British Thomson-Houston Co Ltd the ignition switches in the current pulse generating equipment. Insulating and supporting material for the transformer was supplied by Permali Ltd and cables by Edison Swan Electrical Co Ltd.

The Siemens Centenary

'THE achievement of a century at cricket is no mean feat. It is rightly acclaimed by any standards. It requires qualities of skill and strength, of endurance and vigour, of stoutness of heart and determination of mind, and it requires too—and this point is sometimes overlooked—the wholehearted support of the rest of the team who hold the wicket at the other end and give collectively and in turn of their skill and encouragement and even sacrifice. Most of these things are true also of the achievement of a century by a company. Whereas, however, the cricketer only achieves his century after much practice and experience, those who form a company which has the qualities to endure for a hundred years must, of necessity, gain their knowledge and experience with the passage of time. There is another and even more important difference. Those who found a company cannot in the nature of things survive in person to attain their century. They can, however, as in the case of Siemens Brothers, lay such a foundation of vigorous pioneering and that indefinable something called quality as will itself endure and ensure not only the survival of the company but its constant reinvigoration by new men and fresh minds.'

In these words Dr J. N. Aldington, Chairman and Managing Director of Siemens Brothers & Co Ltd, and Managing Director of Siemens Edison Swan Ltd, began his Centenary Lecture on 5 March 1958, at the Central Hall, Westminster, which inaugurated the celebrations marking the hundredth anniversary of the firm of Siemens Brothers, founded in Great Britain in 1858 by the late Sir William Siemens, DCL, LLD, FRS.

A century of progress

The first part of Dr Aldington's lecture reviewed briefly the state of electrical knowledge at the turn of the eighteenth century. Current electricity was virtually unknown; static electricity had been known for very many years, but little practical use could be made of it. Then, in the first few years of the nineteenth century, the work of Galvani and Volta showed that current electricity could be produced by chemical action, soon to be followed by the Daniel, Grove, Bunsen, and Leclanché cells—the latter being extensively used to-day in the form of the well-known dry battery. Then came Oersted's discovery of the magnetic field surrounding a conductor carrying an electric current; Sir Humphrey Davy's demonstration of the use of current electricity to produce light; and Faraday's fundamental discovery of electromagnetic induction which laid the foundation of the whole technology of electrical engineering.

When, therefore, William Siemens—then a young man of 20—arrived in England in 1843, the stage was set for the remarkable series of developments and inventions in which he played so notable a part. The Company he founded did pioneer work in such varied fields as telegraphy and telephony, the making and laying of submarine cables, the development of the self-excited dynamo and electrical plant of many kinds. It was among the first to work on electric railways and on railway signalling equipment. When the need for central stations and power cables arose following the discovery of the electric lamp, Siemens were in a position to supply complete systems. The company specialized in the development and production of electrical measuring instruments of all kinds, and it was among the earliest in the production of primary batteries, the carbon arc and electric lamps and lighting systems. It introduced into this country the first drawn wire tantalum lamps and has taken part in tungsten filament lamp, electric discharge, and fluorescent lamp developments up to the present time. Siemens Brothers developed and laid the HAIS cable PLUTO to supply petrol across the English Channel during the late war and did much original work on under-sea power transmission cables.

Dr Aldington devoted the main body of his lecture to a survey of the influences which determined the course of these developments during the last 100 years in the fields of communications, power, and lighting, showing that although starting at different times during the last century, they evolved together in three parallel but inter-connected streams. The lecture was illustrated by a number of specially devised demonstrations and lantern slides.

Dr Aldington's lecture was delivered to an invited audience of some 2400 people, with the Rt Hon The Viscount Chandos, DSO, MC, Chairman of Siemens Edison Swan Ltd and Associated Electrical Industries Ltd, in the chair, and Sir Gordon Radley, KCB, CBE, PhD, Director-General of the Post Office, as the closing speaker.

The Sir William Siemens Exhibition

A special Sir William Siemens exhibition was staged in the foyer of the Central Hall on the evening of the lecture, and was subsequently transferred to the Science Museum, South Kensington, London, where it will remain at least until next September.

The exhibition traces his career and achievements in a chronological sequence. The early years, up to his election to the Royal Society, are represented by exhibits relating to his inventions of that period, and to the beginnings of his work with submarine cables. His later work is represented by exhibits dealing with the practice of steel manufacture and with the development of the electrical industry. In the latter, his work on the self-excited generator was of particular importance.

The various threads are brought together in a centrepiece which summarizes his achievements and shows the modern developments to which his work contributed.

On the evening following Dr Aldington's lecture a

Centenary Dinner was held, and among the 1200 present were distinguished guests from various branches of Government, industry and commerce, as well as representatives of the company, many of whom had been in its service for more than forty years. The speakers included Sir Alexander Fleck, KBE, DSc, LLD, FRS, Chairman of Imperial Chemical Industries Ltd; Sir John Cockcroft, OM, KCB, FRS, Member for Research, Atomic Energy Authority; Viscount Chandos; and Dr Aldington. A presentation was made by Viscount Chandos to Mr W. H. Grinsted, OBE, former Chief Engineer of the company, in recognition of his services and the many valuable contributions which he had made to telephone engineering.

Timed to coincide with the centenary celebrations was the publication of a handsomely produced volume entitled *Siemens Brothers, 1858–1958: An Essay in the History of Industry*. Written by J. D. Scott (formerly Literary Editor of the *Spectator*), with a foreword by Viscount Chandos, Chairman of Associated Electrical Industries Ltd, this book traces in its 270 pages the history of the firm, its many developments and technical achievements, its commercial growth and associations, from its foundation in London by William Siemens in 1858 to its present integration as Siemens Edison Swan Ltd within the AEI Group.

Although the personalities of the Siemens family enter largely into the story—the relations of the British company to its German parent, Siemens and Halske, form a major theme of the work—Mr Scott has been careful to keep them in the correct perspective with his subject, which is a history of the British company of Siemens Brothers only. Nevertheless, he has set this against the background of the British scene and its evolution over the last 100 years in a way which makes the book of absorbing interest, not only to readers who are themselves familiar with the electrical industry, but also to all students of industrial history and sociology.

Of unusual interest are the appendices giving a table of relationships of the principal members of the Siemens family; a list of the Chairmen and Managing Directors of the firm from 1858 to the present time, and tables of employment figures at Woolwich from 1897 to 1957.

The book is published by Weidenfeld and Nicholson, 7 Cork Street, London W1, at 35s net.

Demonstration of New Diesel-Electric Locomotive

On 18 April the Eastern Region of British Railways staged a special demonstration run, on the Great Eastern Line between Liverpool Street and Norwich, of one of the new 2000 hp diesel-electric locomotives built by the English Electric Co. Ltd.

As a part of the British Railways modernization plan, the Eastern Region expects to have within the next five years a total of about 400 main-line diesel locomotives, which will be put to immediate use in improving both passenger and freight services pending the completion of the full-scale electrification on the overhead high voltage ac system of most of the Region's main lines.

The locomotive which made the demonstration run was the first of ten now being built for the Eastern Region by the English Electric Co. Ltd. It was hauling nine prototype coaches of different new designs, and in spite of numerous track delays the mile-a-minute schedule (97 kph) was easily maintained, including several scheduled stops on the outward and return journeys. Speeds of over 80 mph (129 kph) were reached on several parts of the run.

Deliveries of the other nine locomotives are being made at the rate of one every two weeks, and this will enable a proportion of the London–Norwich express main-line service to be changed over from steam to diesel-electric traction almost immediately.

The new locomotives are similar in design to the first five main-line diesel-electric locomotives to go into service on British Railways, but incorporate improvements suggested by the experience gained from the 2½ million service miles already covered by the latter. Moreover, the mechanical parts of the new ones are being completed at the works of the English Electric Company's associates—The Vulcan Foundry Ltd—instead of in the British Railways' workshops.

The new type 4 locomotives have a 1 Co–Co 1 wheel arrangement, and are powered by an English Electric 16S VT Mk II diesel engine. This is a 16-cylinder unit, with the cylinders arranged in vee formation, operating on the four-stroke cycle and supercharged by four Napier exhaust gas driven turbo-chargers. The main generator is bolted solidly to the engine, the whole forming a compact and rigid unit. The auxiliary generator is overhung on the free end of the main generator. The complete assembly is supported on resilient bearers so that normal flexing of the locomotive underframe does not set up stresses in the power unit.

The rating is 2000 hp at 850 rpm; tractive effort is 52,000 lb maximum, 30,900 lb continuous. Maximum service speed is 90 mph (145 kph).

Intended primarily as a passenger unit, the new locomotive is entirely suitable for use on freight duties when required. Multiple unit operation is possible, not only with locomotives of its own type, but also with others of various types under construction by British Railways and other manufacturers.

New equipment and processes

'Slim-line' English Electric refrigerator

Recently introduced by *English Electric Co Ltd* is a new domestic refrigerator which, by reason of a highly ingenious design, provides an internal capacity much greater than the compact external appearance would suggest. Appropriately called the 'Slim-line', this new model 7503 measures only 36 in high by 20 in wide by 22½ in deep (91 cm by 81 cm by 87 cm), yet it provides a storage capacity of 3·6 cu ft (102 cu dm) and a shelf area of 6·7 sq ft (62 sq dm).

This result has been achieved by the use of a new low consumption and very compact sealed compressor unit; by providing five alternative levels for the three movable grid-type shelves, a capacious evaporator and chill tray, and a series of shelves on the inside of the full-length door. The table-top of the cabinet is vitreous enamelled and swept up at the back to prevent anything falling down behind.

The cabinet is a steel-welded construction with vitreous top and stoved synthetic enamel body. The food compartment is vacuum formed in one piece from high-impact polystyrene with integral built-in shelf-supports. The door is a full-length box-form steel pressing, rust-proof treated and sealed by a specially developed vinyl plastic gasket.

The hinges have nylon bearings, and a new type of 'pull-open' door-catch is fitted which has no moving parts nor any mechanical connexion with the robust chromium-plated door handle. The inner panel of the door, which is also of vacuum-formed high impact polystyrene, carries a rack for six large eggs, a shelf for small packs or bottles, a full-width 'dairy keeper' with drop-down door and a butter dish, and a deep shelf holding four full-size wine bottles in an upright position.

The English Electric 'Slim-line' refrigerator

The large-size evaporator is of roll-bonded aluminium finished in durable lacquer and fitted with a polystyrene self-closing door. A detachable divider shelf separates the 16-cube, 1 lb (454 g) capacity, moulded polythene ice-tray from packet foods stored in the evaporator, so that the former can be removed without disturbing the latter.

The attractive colour scheme is white or 'new cream' for the exterior; interior of the food compartment, shelves, and inside door panel in light blue.

The electrical equipment consists of a hermetically sealed refrigerator unit with a new type of space-saving, low consumption reciprocating compressor driven by a 1/12 hp single-phase squirrel-cage induction motor with automatic thermal overload protection. The unit is charged with a lifetime supply of oil and refrigerant (Arcton 6), and the compressor and motor are internally spring mounted for quiet operation. The condenser is of tubular construction and mounted vertically at the back of the cabinet.

For use in tropical and sub-tropical climates, a compressor unit of identical specification and dimensions, but with a larger motor, is fitted.

Model 7503 is suitable for ac supplies of 210/240 V 50 cps, or 110 V 50 cps, or 115 V 60 cps. It is not suitable for operation on dc supplies.

The complete refrigerator is guaranteed for one year and the sealed refrigerator unit for a further four years.

Flameproof drill transformer panel for 3·3 kV supplies

Collieries are frequently faced with the necessity of drilling shot holes in the main roadways for maintenance work or other reasons, and since the only power supply available in such locations is often the main ht supply —usually 3·3 kV—the normal medium voltage drill transformer panel for the 125 V drilling machines cannot be used.

To meet this need, *Siemens-Schuckert (Great Britain) Ltd* have producted a special panel containing a 3·5 kVA, 3300/125 V, 3-phase transformer, star/star, with adjustable tappings on the ht side, and the necessary 3·3 kV isolator. The panel is capable of operating two drilling machines on remote control and has been certified flameproof by the Ministry of Power under Certificate No FLP 3940.

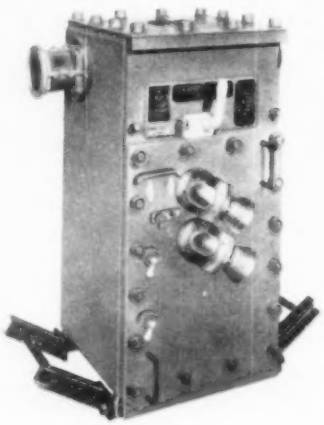
The design of this type DHT 4 panel is similar to that of the medium-voltage draw-out panel BDT 4 made by the Company for some years; the enclosure is of welded steel plate, with two flameproof chambers with large bolted covers, and the main lt apparatus fixed to the door of the lower chamber.

The isolating chamber houses a suitable 3·3 kV triple-pole isolator and fuses, and its handle is interlocked with the front cover. The two lt circuits in the lower chamber are each operated by a triple-pole automatic circuit-breaker having time-lag thermal overload trips and instantaneous magnetic short-circuit trips in each phase. The contactors for remote operation of the drilling machines are controlled by pilot relays energized from a pilot transformer, and the pilot circuits have been certified for intrinsic safety under Certificate No IS 1046.

Earth fault protection is provided by a relay with its operating coil connected between the lt star point and earth. This breaks the contactor control circuits and so opens the main circuits to the drilling machines. An earth fault is indicated through a window in the front cover of the panel, and a press button is provided for regular testing of the earth leakage relay system.

The drilling machines can be reversed when required by a rotation reversing switch in each drill circuit.

The upper isolating chamber contains



Flameproof drill transformer panel

three insulated busbars, and carries 3·3 kV flit plugs on each side for inserting the panel in the lt cable run.

The front cover carries on its inside all the protective and control apparatus, and on its outside the circuit-breaker handles, the rotation reversing switches, and the two-plug socket outlets for the drilling machines. By withdrawing the cover, the whole of the apparatus is exposed and fully accessible for maintenance.

This new panel should greatly facilitate repair and maintenance work in many colliery main roadways which might otherwise have to be done by more laborious and time-consuming hand methods.

Specialized welding equipment

Three welding machines, each designed for specialized applications, have recently been announced by *Sciaky Electric Welding Machines Ltd*, of Slough, Bucks.

Particularly interesting is the model UAM 150, which is designed primarily for research work into spot, seam, roll spot or projection welding but can also be used for production runs if necessary.

To make the machine suitable for practically every kind of metal, the pressure head is pneumatically controlled and provision is made for a one, two, or three pressure cycle. A frictionless roller-bearing diaphragm head is fitted. The fully electronic Sciaky control panel gives accurate timing control from a

half-cycle upwards, phase shift stepless heat control, slope control and pre-heat and/or post-heat. Three synchronous basic Sciaky dekatron timers plus motor control give an almost unlimited combination of machine settings.

Heavy duty spot, projection, seam or roll spot welding can all be done on this machine, and its construction is robust to withstand any stresses likely to be imposed. The machine control circuit and time control equipment are housed in a separate cabinet to eliminate any inaccuracies from vibration, and all the control equipment is easily accessible for maintenance.

Type BSF 1 is a newly developed precision bench spot welding machine for extremely fine work such as valve components, filament wires, contacts, thermocouples and so on. It is an entirely self-contained equipment comprising work bench, weld head, timing control, and transformer, and its design provides ample leg room and freedom of arm movement for the operator.

A fully synchronous electronic timing control of the dekatron type is incorporated, giving visual indicator of the welding period set on the dial. The time range is from a half cycle to nine cycles, adjustable in steps; thyratron valves control the switching of the primary current and in conjunction with an electronic phase shift unit provide stepless adjustment of the welding currents. Coarse heat settings are provided by four tappings on the welding transformer and the precise weld setting is determined by the phase shift, which gives vernier adjustment for critical work. Thus the heat used to effect the weld can be kept to a minimum with consequent reduction in distortion or weld discoloration of miniature parts.

The weld head is of low inertia design and manufactured from high conductivity materials. Electrode force is applied through adjustable springs operated by foot pedal and the makers claim that an exceedingly fine control of pressure can be obtained, with a variation of as little as a few ounces.

Adequate keying action for the weld head is provided to maintain alignment of the welding tips. Electrode holders are of the universal type and can accommodate a wide variety of electrode shapes, while the gap between the tip is adjustable to provide adequate clearance for deep flanged components.

Precision bench spot welder for fine work

The BSF 1 welder can be supplied with transformers of 1, 2, or 5 kVA nominal ratings and with welding heads to give various ranges of electrode force.

The Sciaky range of indexing welders now includes a new model—the PAGM 10—suitable for spot or projection welding or hot riveting, and designed to cater for a wide range of small components.

The table of the machine can be fitted with any reasonable number of jigs or stations. Driving and indexing of the table is by an electric motor through a gear-box giving a range of speeds up to 50 a minute. The air-operated pressure head is fitted with a damper to absorb shock on the down stroke, interlocked with the main mechanism so that the gear is in the clear position when the table indexes.

Welding current supply and control are effected according to the nature of the work. As this is usually small and the welding therefore sensitive, an ignitron contactor is employed together with electronic timing, usually of a synchronous nature.

Various types of unloading mechanism are used—electrical, mechanical, pneumatic, or a combination of these—depending on the nature of the work. Normally, the machine needs only one unskilled operator to load the workpieces into the welding jigs, but it can also be supplied with magazine loading, in which case one operator can feed a number of machines.

Model PAGM 10 has an upper rating of approximately 100 kVA.

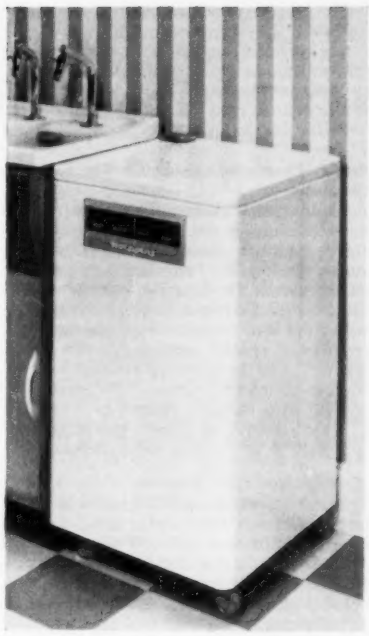
New Hotpoint washing machine

A washing machine which combines two of the main features of previous designs has been produced by Hotpoint Electric Appliance Co Ltd and is to be called the 'Hotpoint Plus 6 Countess'. It incorporates the labour-saving convenience of a safety powered-wringer machine like the 'Hotpoint Empress' with the compactness and simplicity of the 'Hotpoint Princess'.

This model is called the 'Plus 6' because it has six main advantages—the only power wringer on a small-size machine high enough to wring clothes into the sink; a convenient and safe positioning device for swinging the wringer through 90° to wring from sink to draining-board after rinsing; a control panel at a height that needs no stooping and unique in that the setting of all the controls can be read at a glance; it tucks away under the draining-board; has a contemporary look and the exclusive Hotpoint 'no-tangle' washing action which is claimed to give the cleanest wash, without risk of wear to the clothes. The washing action centres in a scientifically-designed plastic gyrator swinging through 218° of arc in a vitreous enamelled square bowl which holds 8½ galls (38 l) of water and is, of course, pumped empty.

Despite the compactness of this machine, the 11 in (28 cm) rollers will wring a full-sized double blanket and the hard and soft rollers give protection to buttons and fasteners. An instantaneous safety release is incorporated.

The four controls are conveniently placed on a panel in the front of the cabinet and operate respectively the 2 kW heater which brings the water to the boil and is fitted with a safety cut-out; the motor with its automatic overload protecting device; the washing action and the pump. On the unheated model there are, of course, only three controls.



The new Hotpoint 'Countess' washing machine

The machine is available in white or cream stoved enamel.

New range of small alternators

Recently announced by the *Macfarlane Engineering Co Ltd* of Glasgow is a new range of their 'Magnicon' self-regulating alternators. Known as the 'RS' series, these machines have been designed to meet the need for a competitively-priced self-regulating alternator in the lower output ranges of 3 to 50 kVA.

By taking advantage of the higher temperature rises specified in BS 2613 : 1957 for Class E insulation and by adopting rotating armature design with an improved field system, it has been possible to produce a very compact machine, and the resulting economies in material have enabled the manufacturers to offer the 'RS' series at lower prices than their existing 'C' and 'L' series.

The machines employ direct-coupled exciters, with the exciter armature hub mounted on a tapered extension of the main alternator shaft. They are normally supplied with the control gear loose for fitting to customers' switchboards and cable tails up to 4 ft (122 cm) long. Alternatively they can be supplied with a casing on the alternator to house the control gear and a terminal board.

Delivery of the 'RS' range is stated to be 10-18 weeks, depending on size, but the manufacturers hope shortly to reduce this to 10-12 weeks for all sizes.

The 1958 Physical Society Exhibition

The 42nd exhibition of the Physical Society was staged in the two halls of the Horticultural Society in London from 24 to 27 March. Altogether there were more than 140 separate exhibitors, comprising the various Government research establishments, learned societies, universities, and commercial firms.

The purpose of this exhibition is to show the latest trends and achievements in scientific research and developments. It is not therefore to be regarded as a trade exhibition showing a range of standard commercial products, but rather as a series of typical demonstrations of the scientific and technical applications of the specialized equipment produced commercially by the exhibiting firms.

This review of the stands of firms who are members of the British Electrical and Allied Manufacturers' Association gives a concise but comprehensive survey of the chief features of interest in each exhibit.

British Thomson-Houston Co Ltd Research Laboratory

Electromagnetic Pumps. The pump enables a conducting liquid to be circulated by electromagnetic forces developed directly within the liquid, thus eliminating moving parts, glands, and seals. For laboratory duty, the single-phase ac conduction pump with combined transformer is convenient; it requires no special supplies and can handle mercury and bismuth or sodium and the sodium-potassium alloys. Two sizes were shown, with nominal ratings of 6 gall/min (27 l), 15 lb/in² (350 g/cm²) and 20 gall/min (91 l), 20 lb/in² (1406 g/cm²), respectively.

High Power CW Klystron. The VX4154 klystron has a collector dissipation of 50 kW and a maximum output of 15 kW, and tunes over the lower end (470-530 Mc/s) of Band 4. It is suitable for AM television service, for FM communication systems using tropospheric scatter, and for certain rf heating applications.

In the first duty a saturation output of 15 kW at some 34 per cent efficiency is obtainable with a synchronizing level of 12 kW at 27 db gain and 6 Mc/s bandwidth. For the second duty full saturation output can be used, with gain up to 40 db with some loss of bandwidth. Saturation output can be used for rf heating, and efficiency increased to 40 per cent at some loss of gain.

Cambridge Instrument Co Ltd

Electronic Type of Conductivity Recorder with Compensation for Quadrature Error. This is a continuous-writing mains operated instrument of high sensitivity, self-contained, and comprising a direct writing recorder with amplifier and chart drive. The measuring circuit is an ac Wheatstone bridge, one arm of which is the measuring cell. The out-of-balance of the bridge emf is taken to a high stability amplifier, the output of which operates the rebalancing motor directly. Temperature compensation is performed automatically by means of a reference cell in the opposite arm of the bridge.

Electrochemical Dissolved Oxygen Analyzer (Gas Phase Transfer Type). This continuously recording and analyzing outfit employs a novel electro-chemical method of detection, developed to meet the most rigid requirements of high pressure and high temperature steam systems now employed in nuclear and other types of power stations. The instrument has a zero of high stability, a high sensitivity, an improved method of calibration, a means of detecting and assessing the size of errors due to leaks in the equipment itself, and it is capable of recording oxygen concentrations to the order of 0·001 part per million.

EMI Electronics Ltd

High Sensitivity Diode Transducer System. This instrument measures mechanical displacement and vibration in both the microscopic and macroscopic fields. The system is based on a diode bridge circuit fed with a rf voltage, the diode circuit being housed in a compact probe and connected by cable to the rf supply unit. The transducer can be operated satisfactorily in the vicinity of strong ac fields and high levels of electrical interference. A range of capacitor elements makes the instrument suitable for a wide field of measurements hitherto only possible with delicate and relatively expensive apparatus.

Measuring Oscilloscope Type WM7. This new instrument incorporates a distributed Y amplifier and signal delay line with a bandwidth from dc to −3 db at 50 Mc/s; the basic sensitivity is 0·1 V/m. The instrument will measure signal voltages directly with an accuracy to 2 per cent in eight ranges from 0·5 V to 100 V. Waveform time measurements can also be made directly with an accuracy to 2 per cent in 15 ranges from 0·5 microsec to 5 secs.

Electronic Dividing Attachment. If the image of a vibrating aperture is projected on to a reflecting surface on which is engraved a line with poor reflecting qualities and if the amplitude of vibration is twice the width of the line, then the reflected light will be modulated dependent on the relative position of the line within the aperture image. Displacement of the line within the image will produce modulation at the vibration frequency, the amplitude being proportional to the displacement and the phase dependent upon the direction of displacement. This principle is applied to a machine for the automatic undercutting of the insulating segments of motor commutators, the reflecting surface being the copper of the commutator segments and the poorer reflecting surface of the insulating slots representing the engraved line.

Photomultiplier Power Supply. This unit provides a highly stable potential, continuously variable between 500 V and 3000 V. The voltage is accurate to ±0·5 per cent of the dial settings. Output voltage will not vary by more than 0·05 per cent for a 10 per cent change in supply voltage. Drift is less than 0·05 per cent for the first hour, 0·1 per cent over 100 hours, and 0·2 per cent over 1000 hours. Ripple voltage is less than 5 mV peak to peak. The unit operates at 90-130 or 200-250 V, 50-60 c/s; approximate power consumption is 170 W.

EMI LogEtronic Photographic Printer Model 1814. This electronically controlled printer extracts the greatest possible detail from negatives by automatic shading during printing. It is a contact printer covering negative sizes up to a maximum of 18 by 14 in (46 by 36 cm), and is especially suited to aerial survey negatives on 9½ in (24 cm) wide roll film and X-ray negatives up to 17 by 14 in (43 by 36 cm). The machine will accept film or plate negatives and will print these on paper, films, or plates.

Ekco Electronics Ltd

Type N563 Gamma Backscatter Gauge. This instrument is designed for the measurement of steel thickness where only one side of the sample to be measured is available. The unit contains an ehv supply for the photomultiplier tube and suitable time constants to remove random fluctuations on the indicating meter. Transistors in association with printed circuits are used in the construction of the equipment which is available for battery or mains operation. The useful range is up to 1 in (25·4 mm) thickness in steel.

Strobograph-Microsecond Waveform Recorder. This is a recording oscillograph for the precise delineation of recurrent high-speed waveforms. 'Strobograms' are produced on standard graph paper 10 by 8 in (25 × 20 cm) in about 30 seconds and no further processing is required.

Elliott Brothers (London) Ltd

Elliott 402F (Floating Point) Computer. This High Speed Digital Computer consists of the 402F (fixed point) computer with three extra cabinets, and can work under programme control either in fixed or floating point mode. The floating point unit of the computer will deal with numbers in the range 2^{-30} to 2^{+31} with sign, numbers outside this range being treated as zero and infinity respectively.

Paper Tape Controlled Compuprinter. This equipment, developed for printing output information from digital computer and data processing systems, is entirely automatic in operation. Information is fed in on punched paper tape via a high speed tape reader, and is then passed to the control unit. The control circuits convert the information into a form suitable for operating the Compuprinter which will print letters, figures and a selection of punctuation marks, etc, at the rate of twenty per second.

General Purposes Analogue Computer G-PAG. This is a single-shot dc computer designed for real time applications, thus permitting the integration of the computer and real equipment in a comprehensive system. A time scale other than real time may be obtained by suitable choice of the computing elements. The method of unit construction permits the scope of the basic computer to be easily extended.

Elliott - Giannini Digital Instrumentation. This equipment is designed to provide complete data handling systems that will produce information in digital form from pertinent physical variables. It is intended for use with existing instrumentation such as self-balancing potentiometers, card and tape punches, and mechanical printers or typewriters.

Transistor Power Unit. Designed to replace rotary convertors and vibrator power units in all types of electronic equipment, the Power Pack Type ETP 1 operates from a 12 V or 24 V battery and covers all dc requirements up to 80 W. Output efficiency is not less than 87 per cent for normal applications. With a built-in filter unit for special purposes the efficiency rating is 80-83 per cent. 6 V units with restricted output are available.

Multi-channel Strip Chart Recorders. These incorporate miniature moving-coil movements arranged to record simultaneously on a single strip chart in banks of 2, 3, 4, 5, or 6 units, each movement recording on a 3 in wide zone. A wide range of chart speeds is available. Applications covering a wide range of simultaneous recordings—for example, three-phase currents and voltages, speeds, revolutions, and frequency—can be recorded simultaneously with a minimum amount of equipment.

Industrial Frequency Indicators. Based on a newly developed full-wave bridge network system, these instruments employ standard moving-coil meters which are available in a variety of sizes and types, including round, square, rectangular, and sector patterns. For a permanent record of frequency variation, miniature recorders with 3 in (76 mm) wide charts can be supplied. Accuracy at the nominal frequency is better than to 1·0 per cent.

Engelhard Industries Ltd, Baker Platinum Division

Thermo-couple Wires. Mechanical weakness of conventional platinum: platinum - rhodium thermo-couples, is stated to be overcome in the new Baker 'Fibro' thermo-couple. The platinum element of this couple retains high strength and ductility after long periods at high temperatures without any sacrifice in calibration. Also recently developed is the 10 per cent rhodium-platinum: 417 Alloy thermo-couple which, up to 1000 deg C, combines the accuracy of calibration and long life of a noble metal thermo-couple with the high emf of a base metal couple.

High Resistance Wire for Potentiometer Windings. The Baker 1729 Alloy provides, in the form of precision drawn fine wire, a high resistance potentiometer winding. The alloy possesses the highest electrical resistivity of any material currently available, combined with the complete freedom from tarnishing and surface film formation associated with the precious metals.

Ferranti Ltd

Ceramic to Metal Seals. Seals have been developed to overcome the limits imposed upon valve performance by the use of conventional glass to metal seals. Several types are available and new developments cover: compression type seals between alumina ceramic and nickel-iron alloy, butt seals between metal and ceramic of matched expansion coefficients, and metallurgical sections of typical ceramic to metal seals.

Semiconductor Devices. Ferranti semiconductor devices are at present confined to silicon diodes and rectifiers of high efficiency and exhibits included examples of 'alloyed' type rectifiers for low power applications and a selection of hv types.

Industrial Valves. A selection of industrial valves was shown, including gas discharge lamps for single and multiple flash operation. One type has a special application to photomicrography, the lamp being run at a greatly reduced intensity for focusing purposes before the main flash. Other types were a modified form of 1 V X-ray tube, fitted with a window to pass a beam for, say, the routine examination of quartz crystal orientation; a new high voltage regulator or control triode, and read-out indicators.

Cathode-Ray Tubes. A range of tubes has been developed to produce radar displays that can be viewed under high ambient lighting conditions. Two ranges of flash tubes are now in production, the CL60 range of 3½ in (8·9 cm) diameter tubes intended primarily for stroboscopic purposes where the area to be illuminated is large, and the CL70 range which is a miniature version (23 mm) diameter and (75 mm) long. It is possible to operate these (vacuum) tubes at very high repetition rates as their performance is not limited by de-ionization time.

The General Electric Company Ltd Research Laboratories

High Expansion Glasses for Sealing to Copper, Nickel, and Stainless Steel. A new range of glasses of high linear coefficients of thermal expansion in the range $15–18 \times 10^{-6}$ per deg has been developed for use as electrical insulators. These coefficients are very similar to those for copper, certain stainless steels, and nickel, so that matched glass-to-metal seals can now be made with these metals in massive form.

Resistivity Measuring Apparatus for Germanium. Using the four-probe method and operating a constant ac source with a voltage amplifier, direct readings of resistivity can be obtained with this equipment in the range 10 milliohm/cm to 100 ohm/cm.

Apparatus for the Investigation of the Dynamic Properties of ac Discharges. Useful data on the behaviour of arc and glow discharges can be found by inserting Langmuir probes into the discharge. Space potential, potential gradient, electron temperature and density, and the ion density of the plasma can be determined and, with the mercury arc rectifier, this information can help considerably in rectifier design.

Radiation Pyrometer. The active element is a series of welded copper-eureka thermo-couples, the hot junctions of which are arranged to receive the incoming radiation, the cold junctions being held at the temperature of the light alloy case in which the element is mounted. The instrument can be used (*a*) as a direct radiation pyrometer for temperatures down to 100 deg C; (*b*) with a double pinhole collimator, to trace isothermals and temperature gradients around a source, as in welding or continuous brazing; and (*c*) fitted with a radiation collecting probe, for measuring high temperatures where the source cannot be viewed directly.

The General Electric Co Ltd

Lamps for Laboratory Use. Among the wide range of Osram laboratory lamps exhibited was the newly designed sodium laboratory lamp. Also displayed were examples from the range of mercury 198 isotope lamps which produce a spectrum in which the spectral lines approach the ideal of true monochromaticity.

New Colour Matching Unit. This new unit overcomes many of the disadvantages associated with the use of 'colour matching' fluorescent tubes. The effect of the strong mercury blue line present in the spectrum of these tubes is largely eliminated by using a balanced combination of three different types of light source: a tungsten filament lamp, a special blue fluorescent tube, and a fluorescent tube with a phosphor which emits radiation in the long-wave uv region, with maximum energy at about 3500Å. In addition to laboratory use, applications for this tube have also been found in the photo-printing and process engraving industries.

Semiconductor Devices. Those displayed included germanium and silicon junction diodes, silicon point contact diodes, and germanium transistors. The GEX541 germanium power diode covers various current and voltage ratings for single- and three-phase bridge networks. The silicon junction diodes include types for rectifier and detector applications at high operating temperatures, also type EW77 Zener voltage reference and limiter diode. Silicon point contact diodes suitable as mixer crystals for X, S, and L bands were shown, and types SIM8 and VX3171 balanced reverse polarity waveguide mixers for Q band. A wide range of germanium transistors included types for low noise applications, and power transistors up to 20 W in a class B stage.

Valves. A number of xenon-filled rectifiers were exhibited, ranging from the GXU50 type, rated at a mean current of 0·25 A, peak inverse voltage 5·2 kV, to type GXU5, rated at a mean current of 3·0 A, peak inverse voltage 10 kV. Others included an indirectly heated half-wave rectifier, E2692, and a grid control rectifier, E2710. Replenisher hydrogen-filled thyratrons were shown, together with two new mercury-filled rectifiers, types GU23 and GU24. The exhibit included the new forced air-cooled triodes valves for rf heating purposes, and type ACT30 for use up to 200 Mc/s, hv rectifiers; travelling wave tube type MW1 for 300 W cw, 2000 Mc/s; spatial harmonic magnetron type MAG8 for 500 MW in X-band, and type E2580 klystron.

Cathode - Ray Tubes. Precision tubes for instrument and industrial purposes included the 4GP and 6EP instrument tubes with one stage of post-deflection acceleration; the 5BHP high sensitivity tube with helical post-deflection acceleration system; type 3WP1 3 in (76 mm) high definition, high sensitivity precision oscilloscope tube; and 5ADP 5 in (127 mm) close tolerance tube with one stage of post-deflection acceleration. A new tube is type LD517—a 5 in (127 mm) double-

gun, high sensitivity oscilloscope tube with a helical post-deflection acceleration system.

Johnson, Matthey & Co Ltd

Electrical Contacts. A variety of electrical contacts in a number of different alloys was shown, these including standard ranges of headed contacts, button contacts for resistance welding to their supports, and tubular contacts. These contacts, which are available with head diameters up to $\frac{3}{8}$ in (9·5 mm), comprise a copper shank and backing with an integrally bonded facing of fine silver. The tubular shank greatly facilitates assembly.

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Metropolitan-Vickers Electrical Co Ltd

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12-Element Electromagnetic Oscillograph. This instrument records 12 simultaneous quantities up to 500 V dc on film or paper of 250 mm maximum width. The recorder is operated from ac mains and provision is made for automatic initiation of circuits under investigation. Timing marks at 40, 200, 1000, and 5000 ms are made by a discharge tube controlled by a quartz crystal and count down circuits. The drum-type recording camera is driven by a variable speed motor through a gear-box, giving a camera speed range of 1 to 400 rev/min.

The Morgan Crucible Company Ltd

Silicon Carbide-Graphite Thermo-couples. This thermo-couple consists of an inner graphite rod cemented into an outer silicon carbide tube, approximately $\frac{3}{4}$ in (19 mm) diameter and 12 in (305 mm) long. It should be possible to use the thermo-couples to about 1900 deg C without a protective sheath. In addition, voltages in the order of 250-500 mV are obtained in the range 1000-1900 deg C.

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Mullard Ltd

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Philips Electrical Ltd (Research and Control Instruments Division)

X-ray Generator PW 1010. This highly stabilized generator energizes the diffraction tubes. Optimum individual stabilization of the hv and tube current dispenses with the necessity for monitoring systems. The stabilized direct voltage may be adjusted between 10 and 54 kV with tube current between 6 and 36 mA in steps of 2 mA. Automatic electrical, cooling water, and radiation protection devices are included in the circuitry.

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regulation to ±0·1 per cent at 2000 V for a mains fluctuation of ±10 per cent.

High and Low Angle Diffractometer PW1050. This precision instrument offers a means of recording directly the intensity and angular disposition of the various diffracted lines produced by the material under test. Intensities can be measured simultaneously with a very high degree of accuracy and without the need for monitoring or photometry.

Spectrographic Attachment PW1520. A precision casting positions the specimen face, high intensity tube, analyzing crystal, slit systems, vacuum chamber, and radiation detector in their correct relative positions for the analysis of elements contained in the sample. The complete X-ray set when modified for fluorescent analysis offers a quick, accurate, fundamentally simple, and non-destructive method of physical analysis.

Gas Refrigerating Machine PW7000. This is a small, self-contained, single cylinder water cooled gas liquefier built on the displacer principle, obtaining, within fifteen minutes, temperatures in the range of −80 to −200 deg C in a single stage. The machine will liquefy those gases which condense at temperatures above −200 deg C, the rate being determined by the characteristics of the gas or gas mixture.

Salford Electrical Instruments Ltd

Magnetic Materials. The ferrites exhibited included those used in pulse delay lines, storage devices, frequency modulation equipment and miniature transducers. These applications are covered by a range of discs, bars, pots, and 'E' cores. In addition, there is a range of miniature types of pot, cup, screw, and 'pencil lead' cores.

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Siemens Edison Swan Ltd

DC Stabilized Power Supply Units. The R2130 unit provides a highly stabilized dc output, continuously variable, between 90 and 600 V. The load is 500 mA. A further unstabilized supply is provided, variable between 240 and 750 V, load 500 mA. Two 6·3 V, 5 A, ac heater supplies are also available.

The R2140 unit provides a highly stabilized dc output of either 250 V or 300 V; the load is 250 mA. Two unstabilized 6·3 V, 4 A, ac heater supplies are available.

The R2001 power unit is designed to replace batteries. It provides a stabilized dc output continuously variable between 0 and 100 V. The load is 50 mA. There is a second stabilized output of 250 V at 5 mA. A change of 10 per cent in the mains supply results in an output voltage change of less than 0·1 V. The output impedance is less than 1 ohm. Ripple is less than 1 mV peak to peak.

The R2030 1 V unit is designed to replace a 6 V accumulator. The dc output is continuously variable between 0 and 8 V. The load is 4 A. An unstabilized 6·3 V, 5 A, ac heater supply is provided. A change of 10 per cent in the mains supply results in an output voltage change of less than 15 mV. Output impedance is less than 2·5 milliohms. Ripple is less than 3 mV peak to peak.

Ferrite Core Keysender and Prototype Register. Faster and less fatiguing telephone signalling can be obtained with a keyboard-type instrument, the number keyed first being stored and then released as a series of impulse strains exactly similar to those generated by the standard dial. In the model keysender exhibited, this storage is done with ferrite cores and the number keyed is displayed on a prototype dekatron transistor register.

Transistors. A range of transistors for rf and audio applications was shown, including the XA102 with an average frequency cut-off of 8 Mc/s, and the XC101 for push-pull audio outputs. Examples of a new type of high frequency and power transistor were also exhibited.

Valves, etc. A selection of recently developed valves, cathode-ray tubes, and metal-glass seals was shown.

Solus-Schall Ltd

X-ray, Diffractometer No. 50200. This instrument with its associated electronic ratemeter/amplifier and chart recorder, etc, is used to determine the position, intensity, and width of diffraction lines from polycrystals or from single crystals in the plane of motion of the counter tube. The Diffractometer is also suitable for X-ray fluorescence and chemical analysis, quartz, and fibre orientation techniques, and low angle scattering from clay specimens, etc.

Electronic Fast Counting Ratemeter/Amplifier No. 50211. This is used for X-ray diffractometry, incorporating a stabilized ehv supply, variable gain control, discriminator, cathode follower output circuit for a scaler, and ratemeter ranges from 0 to 100,000 pulses per second.

Ultrasonic Flaw Detector. This detector is used for the non-destructive examination of machined parts, forgings, welded joints, and the determination of wall thickness, etc, and employs a frequency pulse echo vibration technique registering on an oscillograph screen which can be recorded photographically.

NOTES (*continued from page 80*)

Second Geneva atom conference

The second International Conference on the Peaceful Uses of Atomic Energy will be held in Geneva from 1 to 13 September 1958. The president of the Conference is to be Professor F. Perrin of the Commissariat à l'Énergie Atomique de France, and the Secretary-General is Dr D. Eklund of Sweden.

During the conference, two atomic energy exhibitions will be staged, as was done at the previous conference in 1955. The first of these—at the Palais des Nations—will be a scientific exhibition under the auspices of the United Nations. The UK exhibit here, covering some 5000 sq ft (465 sq m) is being arranged by the Atomic Energy Authority, and a prominent feature will be a model of Zeta—the apparatus responsible for the world's first successful achievement of thermo-nuclear fusion.

The second exhibition—the International Exhibition of the Peaceful Uses of Atomic Energy at the Palais des Expositions—will be commercial in character. Here the British section is being organized by the Nuclear Energy Trades' Association Conference (NETAC), and its great size (more than 30,000 sq ft (2787 sq m), and the large number of firms participating (more than 50) will emphasize Britain's world leadership in atomic energy development and utilization. It will include an exhibit by the Atomic Energy Authority.

The UK delegation is expected to consist of 5 delegates, about 250 advisers, and about 250 observers, headed by Sir John Cockcroft, Member for Scientific Research of the United Kingdom Atomic Energy Authority. The other 4 delegates will probably be a second representative of the Atomic Energy Authority and representatives of the Royal Society, British Industry, and the Medical Research Council.

Some 200 papers from UK sources have been selected by the Papers Committee under the chairmanship of Dr B. F. J. Schonland for submission to the United Nations. Their approximate distribution is 60 per cent from the UK Atomic Energy Authority; 22 per cent from industry; and 18 per cent from the Medical Research Council, hospitals, universities, and similar bodies.

Obituary

We record with regret the deaths of the following well-known personalities in the electrical industry.

C. Leslie Wates, JP, Comp IEE. On 22 Jan. 1958, after a long illness. Mr Wates became associated with *Johnson & Phillips Ltd* in 1907; was made a Director in 1927 and became Chairman in 1931. On his resignation, because of failing health, was appointed Honorary Chairman of the Board.

Chairman of the Cable Makers' Association, 1946/47. Chairman of the Council of the BEAMA, 1950/51, when he initiated a scheme for endowing a Chair of Electrical Engineering at Cambridge University.

J. P. A. Meldrum, OBE. Together with his wife, he met a tragic death in a car accident on 20 Jan. 1958. Educated at Rugby and Glasgow University, Mr Meldrum joined *Metropolitan-Vickers Electrical Co. Ltd.* in 1926. After distinguished war service in the Royal Corps of Signals, he was appointed Sales Manager, Switchgear Department. In 1953 he was made Manager, Home Sales; appointed a Director in 1955, and became Sales Director in January last year.

Sir James Swinburne, Bt, FRS. Died 30 March 1958, soon after his 100th birthday. Often described as 'the Father of the Plastics Industry' for his extensive and fundamental work on the phenolic resins. He also did a great deal of development work in the design of electrical instruments.

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Valves, etc. A selection of recently developed valves, cathode-ray tubes, and metal-glass seals was shown.

Solus-Schall Ltd

X-ray, Diffractometer No. 50200. This instrument with its associated electronic ratemeter/amplifier and chart recorder, etc, is used to determine the position, intensity, and width of diffraction lines from polycrystals or from single crystals in the plane of motion of the counter tube. The Diffractometer is also suitable for X-ray fluorescence and chemical analysis, quartz, and fibre orientation techniques, and low angle scattering from clay specimens, etc.

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NOTES (*continued from page 80*)

Second Geneva atom conference

The second International Conference on the Peaceful Uses of Atomic Energy will be held in Geneva from 1 to 13 September 1958. The president of the Conference is to be Professor F. Perrin of the Commissariat à l'Énergie Atomique de France, and the Secretary-General is Dr D. Eklund of Sweden.

During the conference, two atomic energy exhibitions will be staged, as was done at the previous conference in 1955. The first of these—at the Palais des Nations—will be a scientific exhibition under the auspices of the United Nations. The UK exhibit here, covering some 5000 sq ft (465 sq m) is being arranged by the Atomic Energy Authority, and a prominent feature will be a model of Zeta—the apparatus responsible for the world's first successful achievement of thermo-nuclear fusion.

The second exhibition—the International Exhibition of the Peaceful Uses of Atomic Energy at the Palais des Expositions—will be commercial in character. Here the British section is being organized by the Nuclear Energy Trades' Association Conference (NETAC), and its great size (more than 30,000 sq ft (2787 sq m), and the large number of firms participating (more than 50) will emphasize Britain's world leadership in atomic energy development and utilization. It will include an exhibit by the Atomic Energy Authority.

The UK delegation is expected to consist of 5 delegates, about 250 advisers, and about 250 observers, headed by Sir John Cockcroft, Member for Scientific Research of the United Kingdom Atomic Energy Authority. The other 4 delegates will probably be a second representative of the Atomic Energy Authority and representatives of the Royal Society, British Industry, and the Medical Research Council.

Some 200 papers from UK sources have been selected by the Papers Committee under the chairmanship of Dr B. F. J. Schonland for submission to the United Nations. Their approximate distribution is 60 per cent from the UK Atomic Energy Authority; 22 per cent from industry; and 18 per cent from the Medical Research Council, hospitals, universities, and similar bodies.

Obituary

We record with regret the deaths of the following well-known personalities in the electrical industry.

C. Leslie Wates, JP, Comp IEE. On 22 Jan. 1958, after a long illness. Mr Wates became associated with *Johnson & Phillips Ltd* in 1907; was made a Director in 1927 and became Chairman in 1931. On his resignation, because of failing health, was appointed Honorary Chairman of the Board.

Chairman of the Cable Makers' Association, 1946/47. Chairman of the Council of the BEAMA, 1950/51, when he initiated a scheme for endowing a Chair of Electrical Engineering at Cambridge University.

J. P. A. Meldrum, OBE. Together with his wife, he met a tragic death in a car accident on 20 Jan. 1958. Educated at Rugby and Glasgow University, Mr Meldrum joined *Metropolitan-Vickers Electrical Co. Ltd.* in 1926. After distinguished war service in the Royal Corps of Signals, he was appointed Sales Manager, Switchgear Department. In 1953 he was made Manager, Home Sales; appointed a Director in 1955, and became Sales Director in January last year.

Sir James Swinburne, Bt, FRS. Died 30 March 1958, soon after his 100th birthday. Often described as 'the Father of the Plastics Industry' for his extensive and fundamental work on the phenolic resins. He also did a great deal of development work in the design of electrical instruments.

Book Reviews

Analytical Design of Linear Feedback Controls. *By G. C. Newton, Jr, L. A. Gould, and J. F. Kaiser.* 9¼ × 6 *in* (235 × 152 *mm*). *Pp xi* + 419. *Index.* (*London: Chapman & Hall; New York: Wiley*, 1957). Price 96s net.

Many books have been published on the theory of linear feedback controls, but none has covered exactly the same ground as this volume, few have covered even a proportion of its contents as exhaustively, and very few have had its clarity of exposition.

The main theme running throughout the book is a method of design of feedback control systems whereby it is ascertained at an early stage whether a performance demanded in the system specifications can or cannot be met. This is in contrast to the trial and error design procedure where no criterion is provided for terminating the sequence of trials when difficulty is encountered in meeting the specifications. The system specifications include descriptions of the input, the disturbances, the desired response, and a system performance index. Analytical design theory is the name given to minimizing (or maximizing) the chosen performance index in an idealized model representing the physical equipment.

A comprehensive discussion of the analytical design procedure is given as applied to two performance indices. These are the integral-square error for systems subject to transient input signals, and the mean-square error for stochastic input signals. The choice of performance indices is not an easy matter as such indices must be susceptible to mathematical treatment, and must tend to minimize (or maximize) other parameters that are of a more direct character but that are not susceptible to mathematical treatment. The field of control systems is by no means isolated in containing such performance indices.

Chapter 1 contains a brief history of the art of feedback control—apparently dating back about four thousand years to an irrigation system used by the Babylonians—together with information on the basic block diagrams and notation. Minimization of the integral-square error through parameter adjustment is discussed in Chapter 2, and useful tables are given in an Appendix to facilitate the calculation when the Fourier transform of the error is a rational function of the complex frequency. After an introduction to stochastic signals and correlation functions in Chapter 3, the minimization of the mean-square error through parameter adjustment is discussed in Chapter 4. A variational approach to the problem of minimizing the mean-square error for systems possessing no fixed elements is presented in Chapter 5, while this approach is extended in Chapter 6, for both mean-square and integral-square error, to systems having fixed elements that are beyond the control of the designer. How to avoid saturation within the fixed elements is the subject of Chapter 7, while the design of control systems for minimum bandwidth when the value of a performance index is specified is discussed in Chapter 8. Much of the analytical design theory of the previous chapters is put to practical use in Chapter 9, which discusses in detail the problem of the azimuth drive for the proposed National Science Foundation radio telescope, containing a 140-foot diameter parabolic reflector. The reader is given an understanding of how analytical design theory is used in conjunction with trial and error design techniques to solve practical problems.

Five appendices covering more than one hundred pages conclude this book. The first gives the basic properties of Laplace and Fourier transformations that are necessary for the understanding of the text, the second presents the stability criteria of Nyquist, and Routh and Hurwitz, while the third gives a review of conventional design techniques including the Bode diagram, feedback compensation, the root-locus method and the determination of transient response from frequency response. The fourth appendix details trial and error methods in the gain phase plane, including the Nichols chart and lead and lag function curves, while the fifth gives an evaluation and table of integrals encountered in the text. Four charts are included in the pocket at the rear cover of the book to facilitate the application of techniques described in the appendices. The appendices as a whole provide a very valuable addition to what would, even in their absence, constitute an exceptionally useful book.

The knowledge of mathematics needed for the understanding of this book is not so difficult as to be prohibitive provided that the reader has an initial knowledge of complex variable and Laplace transformation techniques, and has had some graduate training. Many engineering fields are beginning to involve more mathematical techniques, and the basic mathematical training for engineers is being adjusted to meet these requirements.

It will be interesting to note how the use of digital computers will change the techniques of feedback control system design, in so far as many of the numerical methods detailed in this book as tedious and lengthy appear quite suitable for speedy solution with the aid of digital computers.

Finally, I consider this book is a worthy addition to the bookshelf of anyone concerned with the design of feedback control systems. The printing and reproduction are excellent.

Electronic Measuring Instruments. *By E. H. W. Banner. 2nd edition revised.* 9 × 6 *in* (229 × 152 *mm*). *Pp xvi* + 496. *Illustrated. Index.* (*London: Chapman & Hall*, 1958.) Price 56s net.

It is perhaps a little difficult to offer criticism of a book which has sold well enough to justify a second edition, but one cannot help wondering what is the real, practical use of this work as it stands. A lot of labour has gone into its preparation, and if one wants a very broad survey of the subject matter indicated by its title it can be well recommended. Electronics is claiming an ever-increasing place in modern engineering and there is some justification for a survey which gives the busy industrial engineer or engineering student an idea of the ramifications of electronics, but hardly at the price of an expensive book.

The operating principles of a very large number of devices are given, but where the devices are not commercially available one could hardly carry out further developments on those principles from the data given. On the other hand, if the devices can be purchased, one is not so much interested in operating principles as in performance, characteristics, limitations, special advantages, etc, which could have been given in greater detail.

Another weakness of the book is that it contains much that already exists in established textbooks, or is more properly dealt with in specialized books. This is particularly true of transistors.

For a third edition it is suggested that all standard textbook material should be omitted, also mention of highly specialized instruments which are rarely used, unless perhaps they are readily available as catalogue items.

Surveys of a subject have a place in engineering, but costs should be kept to a minimum, even if it is necessary to introduce a lot of tabular material, and a 'catalogue atmosphere'.

J. H. J.

Nuclear Power Reactors. *Edited by James K. Pickard.* 9¼ × 6 *in* (235 × 152 *mm*). *Pp xii* + 388. *Illustrated. Index.* (*New York: D. Van Nostrand*, 1957.) Price 64s net.

This book is one of the Geneva Series on the Peaceful Uses of Atomic Energy of which, with the present volume, six have been published. The Geneva Conference, it will be recalled, was held in August 1955, and many hundreds of technical papers were presented by experts from all over the world. Each volume of the Series constitutes a carefully arranged and edited selection of the information contained in the key papers on a specific feature of nuclear science, and the present book is concerned with reactors as a source of heat for electric power production.

The first three chapters are of a general character and they deal with nuclear power prospects, nuclear fuel cycles and reactor types, and the economics of nuclear power. The remaining six chapters cover particular types of reactors: pressurized-water reactor plants, boiling-water reactors, homogeneous and circulating fuel reactors, sodium-cooled graphite-moderated reactors, and fast reactors.

In all these chapters a considerable amount of valuable information is given on the basic design of the various forms of reactors; on construction, materials, costs, safety measures, controls, and operating experience, as well as on some of the major physics problems of nuclear reactor theory and practice.

The countries contributing to this volume are the UK, Canada, the USA, the USSR, Norway, and the Netherlands. A list is given of the Geneva Conference papers relevant to nuclear power reactors, and

subject and name indexes complete the work.

The editor of the book in the preface says: 'While the material devoted to specific design of the various reactor types will undoubtedly show its age with each year, the information concerning over-all selection of reactor types and the nature and description of the fuel supply problems which are basic to the atomic power industry should retain its usefulness'. He is no doubt right for the next ten or twenty years—Zeta permitting!

The book is a really valuable record of nuclear power reactor practice to date, and the editor has done a first-class piece of work in welding the relevant Geneva papers into such a consistently readable whole. The printers and publishers too are to be congratulated on having produced a text so easy on the eye.

S. AUSTEN STIGANT

Electrical Technology. *By H. Cotton. 7th edition.* $8\frac{3}{4} \times 5\frac{1}{2}$ *in* (222 × 140 *mm*). *Pp xv* + 866. *Illustrated. Index.* (*London: Sir Isaac Pitman & Sons*, 1957.) Price 50s net.

The writing of a textbook for the use of undergraduates, on any subject, is a formidable task that daunts all but a minority of would-be authors. In many cases the selection of the actual contents is determined by an avowed aim to cover a set syllabus for a given external or similar examination. In many other cases the inspiration may be due to the author having expert knowledge of a specialized and restrictive topic frequently included as an item in some syllabus. It does appear, however, that almost all textbooks inevitably reflect the personal knowledge, experience, opportunities, environment, and interests of the author. In particular, books normally show the effect on the author of discussing with colleagues the theoretical and practical conceptions of the subject. This cross-fertilization of ideas helps an author to surmount the difficult parts of the subject matter in a manner that is acceptable to a student.

In addition, most textbooks usually contain certain topics to which the author gives undue emphasis. This detailed treatment usually arises from a particular fascination or experience of this part of the subject. This emphasis, if a fault, is, however, offset by the benefit derived from the unity, continuity, and style derived from the work of a single author. It must be admitted, however, that all too often textbooks are slavish copies of poorly conceived and ill-digested lecture notes.

It is in the light of those considerations that the seventh edition of this well-known textbook should be considered. Although the present edition has been completely revised and extended, it still retains the same general style and format of the original book published over thirty-three years ago.

The subject matter of the contents covers, in a traditional manner, mainly the material normally considered appropriate for inclusion in an undergraduate course in electrical machines, and nowhere can it be said to be a mere presentation of lecture notes.

It does, however, show clear evidence of the time spent by the author in teaching the Old Regulations degree syllabus of the Design and Performance of Electrical Machines, and the effect of discussion in elucidating some difficult points. For good or ill, much of this material has now been removed from the revised syllabus on Electrical Power and Machines, so that to some extent certain topics are now inappropriate for undergraduate study.

This volume is large, containing 866 pages, since the author has planned the contents so that the book comprises all that the student, starting at advanced level GCE in mathematics and physics, will require to know in this subject during the whole of his degree course. It is difficult to see how the size of the book, if the avowed aim is to be maintained, could be reduced, for not only are the majority of the topics those generally accepted as essential, but the author cannot be accused of padding. It is possible that many would prefer some of the design considerations eliminated as being undesirable in an undergraduate course. These do not, however, occupy more than a minor part of the text. One suggestion would be to assume that the student has passed Part I of the degree examination, or its equivalent, and so eliminate much of the basic electrotechnology. In any case this technology is appropriate to all branches of electrical engineering, and there is no particular reason for its inclusion in a book mainly concerned with electrical machines, in the same way as there would be no justification for its inclusion in a book on electronics. There is far too much repetition of standard subject matter in nearly all textbooks.

There is a large number of fully worked numerical examples to illustrate the more important parts of the subject matter. The author has also provided a large number of problems, with answers, for the reader to solve so as to give confidence in his studies.

The general style of the book is that now usually associated with the author who writes with an easy flow of words, enabling the text to be read without difficulty. Although the treatment of certain topics will not please some readers, the book cannot but be of help to students who will require to study, even if only a small part, the subject of electrical machines and plant in their undergraduate course. The book is clearly printed on good quality paper and is well recommended.

P. F. S.

High Quality Sound Reproduction. *By James Moir.* $9 \times 5\frac{1}{2}$ *in* (229 × 140 *mm*). *Pp xiv* + 591. *Illustrated. Index.* (*London: Chapman & Hall*, 1958.) Price 70s net.

The author very rightly enjoys the highest possible reputation in this comparatively new field of electrical engineering, and he has produced what will become to be regarded as a textbook which, with revisions as appropriate as the new editions succeed each other, will remain pre-eminent in its own sphere for very many years.

Mr Moir starts by discussing, in a remarkably objective manner, the characteristics of music, speech, and noise. Then he takes us actually inside the human ear, so that we become thoroughly familiar with the working of the organ without which the whole of the science of sound reproduction would have no meaning. It is interesting to note that Mr Moir commences this paragraph by saying that 'A study of the human hearing mechanism is an interesting and humbling experience to the communications engineer. The engineer and Mother Nature have both had the same problem, that of producing a device that will convert acoustic energy into electrical energy, and so far Mother Nature has produced the superior instrument.'

He then discusses the performance of the hearing system in relation to the effect of noise and loudness, and starts very naturally on the technical section of the book with an exposition of the type of instrument through which sound is first converted into electrical impulses—the microphone.

It might have been thought that the next logical step would have been to the amplifier, but instead Mr Moir takes us unto the disc and the tape fields, and explores them both with the utmost thoroughness. Then the whole range of electrical circuitry concerned with the amplification of the electrical impulses which are made to represent every kind of sound are dealt with.

The third and last natural division of the subject is that concerned with means for the reproduction of sound. Here we find chapters on loudspeakers, on the acoustic problems of almost every kind of room or hall, including the cinema, and finally we are given an extensive survey of the future in terms of stereophonic sound reproduction.

Throughout this admirable survey of an increasingly important subject the argument is clear and is not too highly mathematical for the general reader with some knowledge of simple radio techniques; it is amply illustrated with clear diagrams and occasional photographs, and it is reasonably well indexed for rapid reference.

Taking all in all this book can be unreservedly commended.

J. H. M. S.

Pressure Measurement in Vacuum Systems. *By J. H. Leck.* $9\frac{1}{2} \times 6$ *in* (241 × 152 *mm*). *Pp* 144. *Illustrated. Index.* (*London: The Institute of Physics*, 1957.) Price 30s net.

In six chapters this book describes the different methods of pressure measurement in common use and gives an account of the theoretical background as well as of the practical aspects of gauge design, the latter including numerous examples of designs taken from the literature of the subject.

The chapters cover mechanical manometers, thermal conductivity gauges, ionization gauges, the Knudsen radiometer gauge, surface reaction techniques, and gauge calibration. Of these, the mechanical and radiometer manometers are absolute pressure gauges, while the remaining three types are indirect since they involve the measurement of some secondary phenomenon which is pressure-dependent.

The book is well illustrated by line drawings of gauge designs, control circuit diagrams, and performance graphs. There is a four-page list of reference, a subject index, and a name index.

The work provides a reliable guide to the selection, application, and characteristics of pressure gauges and it should be most useful to those working in the fields of vacuum physics or engineering.

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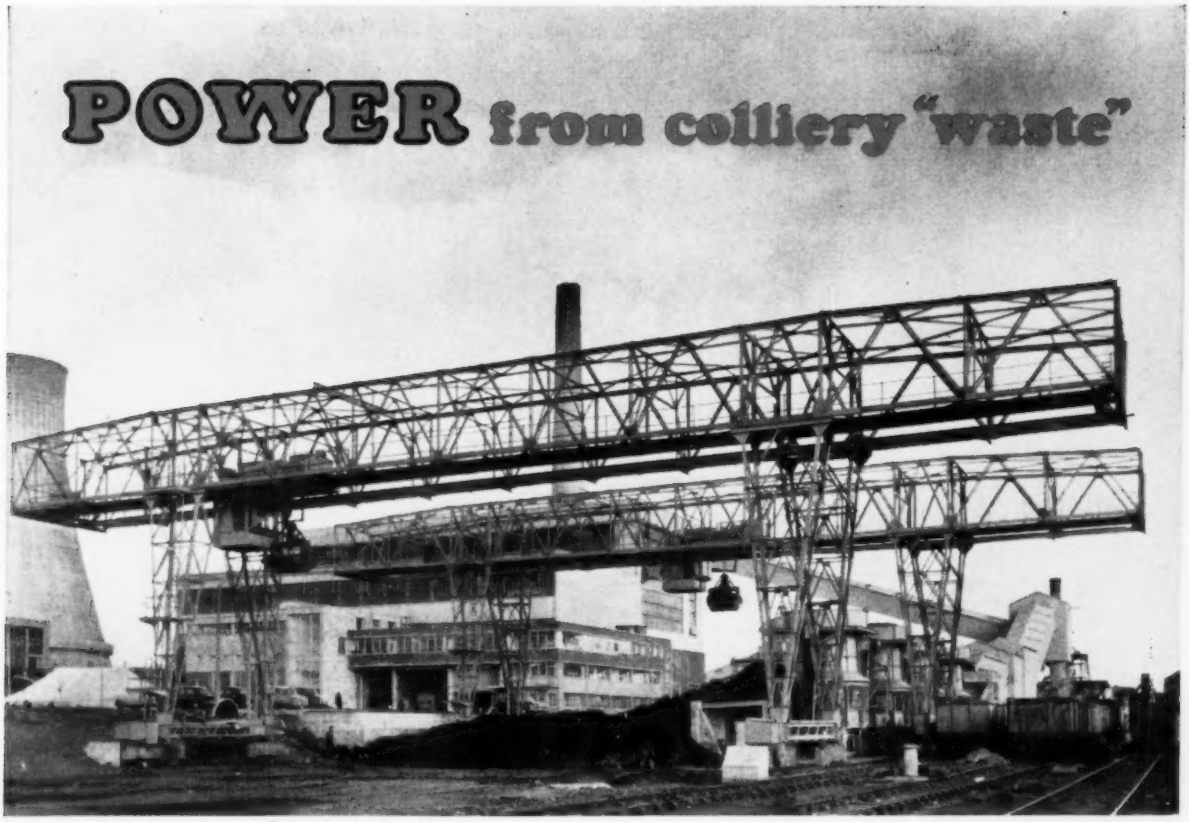
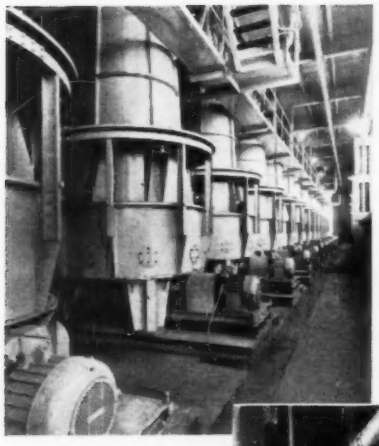
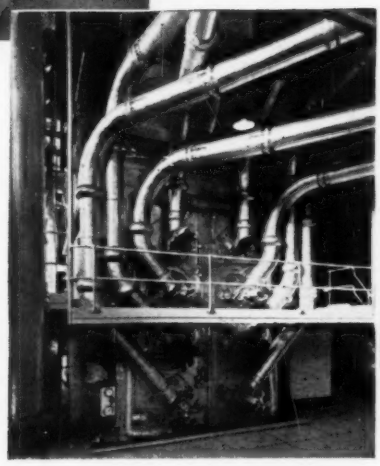


Barony power station, showing Babcock cranes, rotary hoppers and fuel conveyor system.



Line of Babcock rotary hoppers for handling slurry to the drying and pulverizing mills feeding the boilers.



P.F. burners and fuel piping on one of the boilers.

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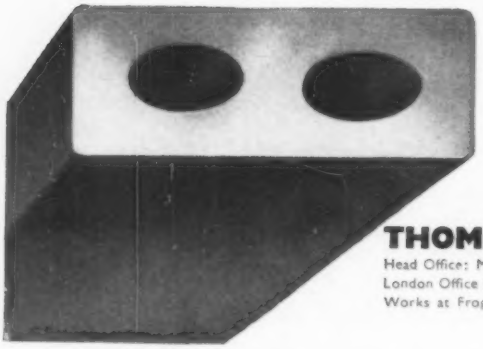

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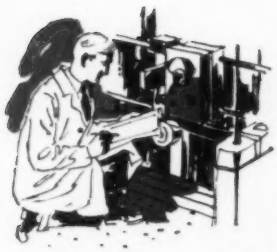

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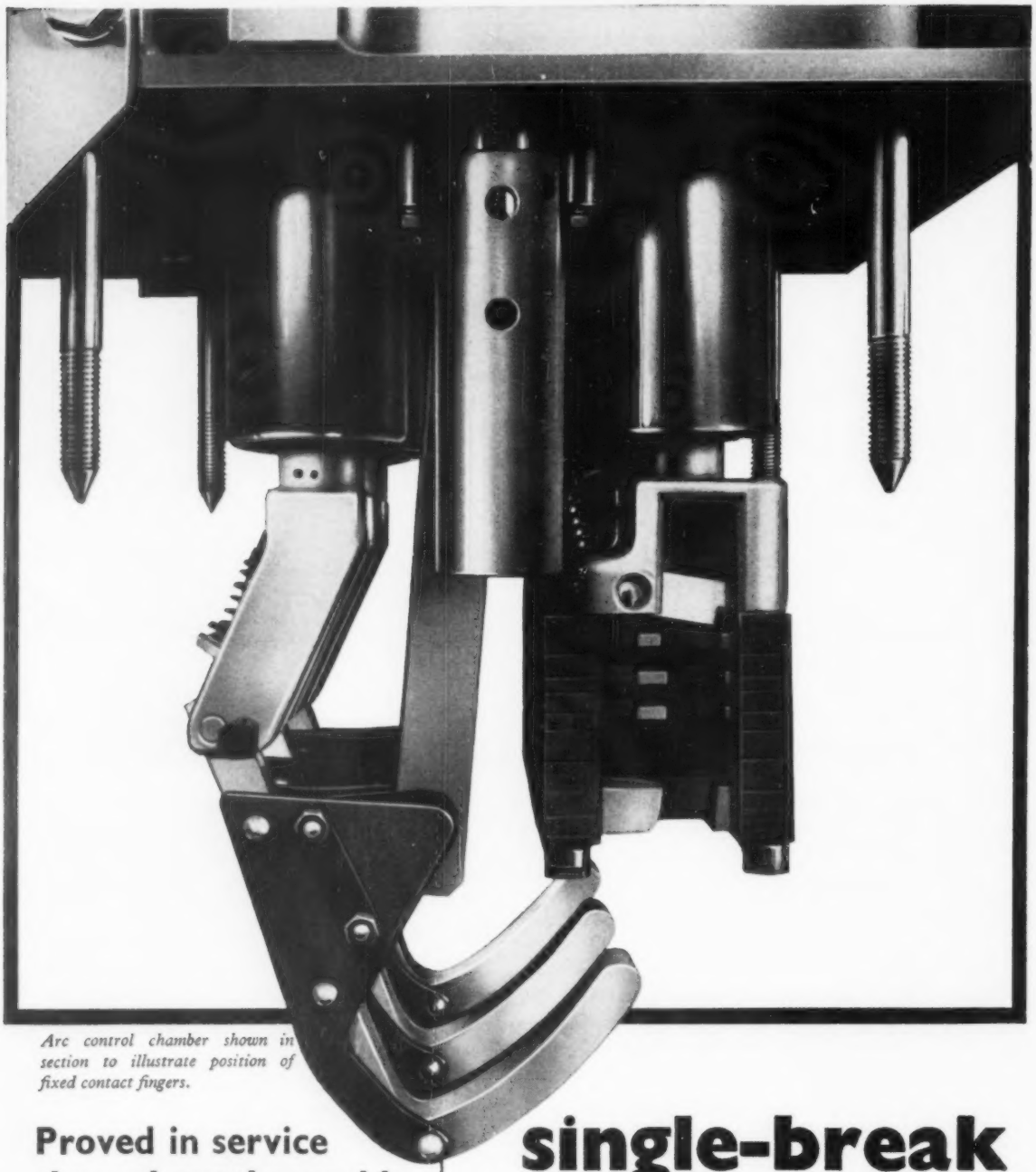

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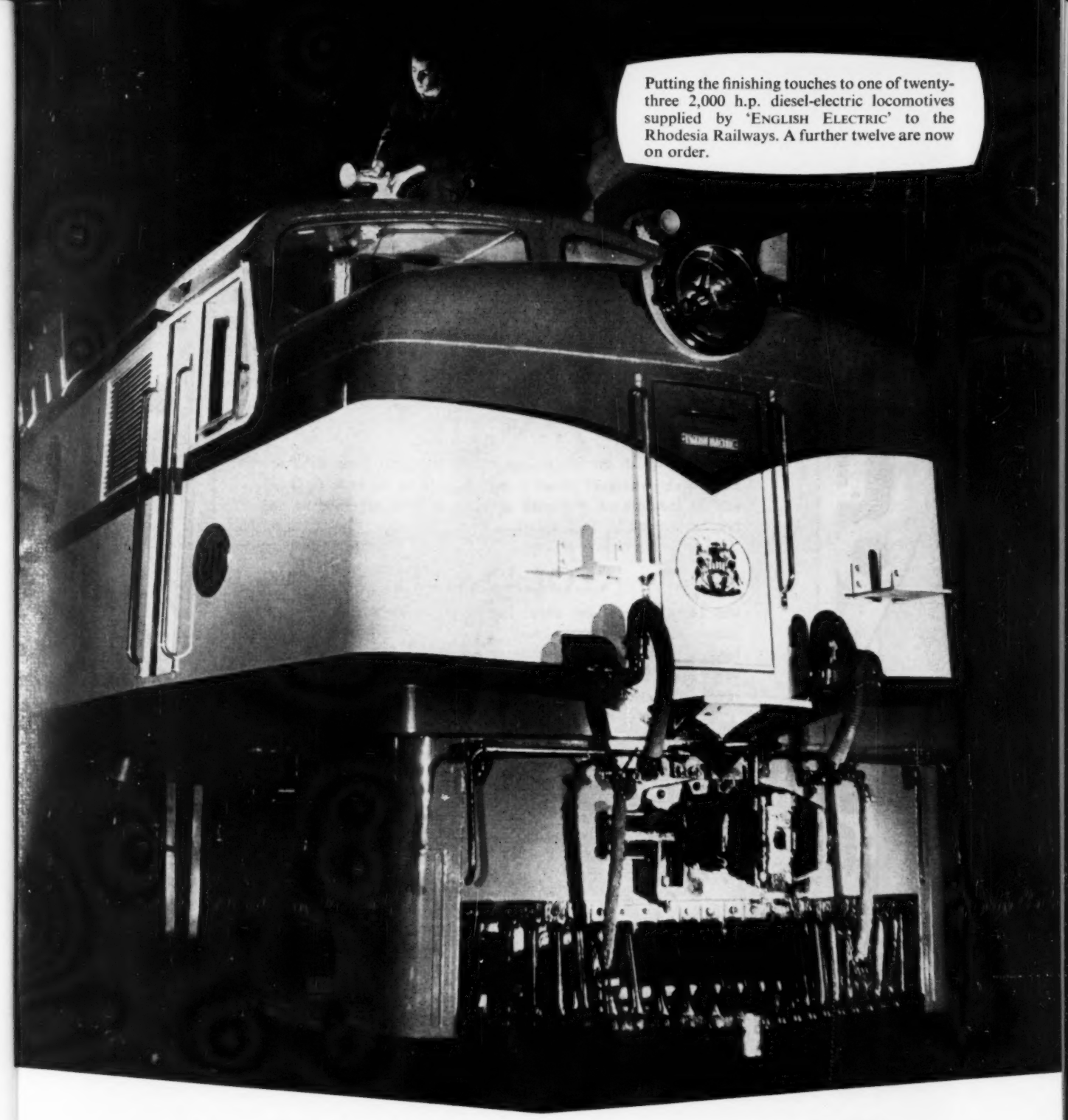

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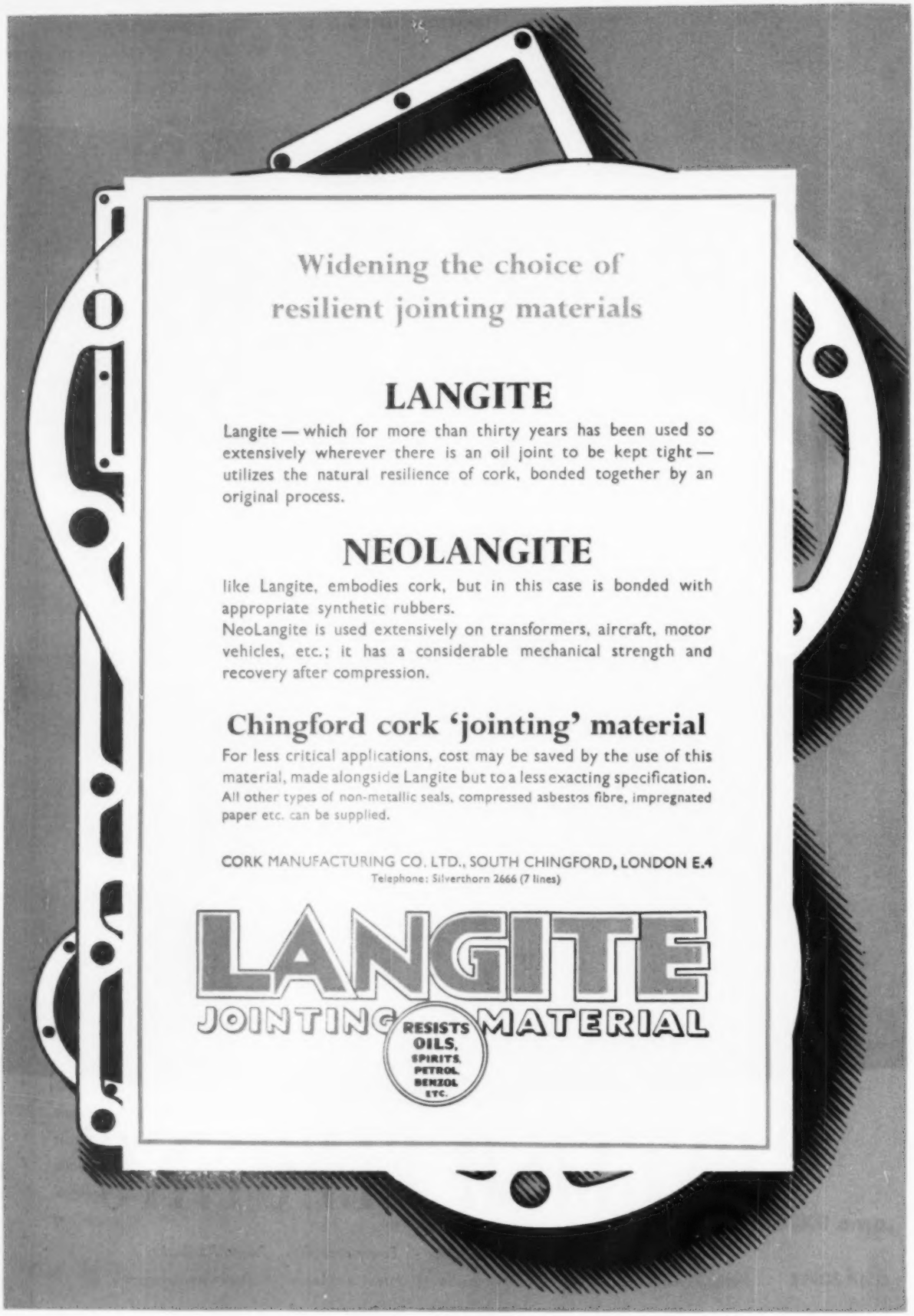
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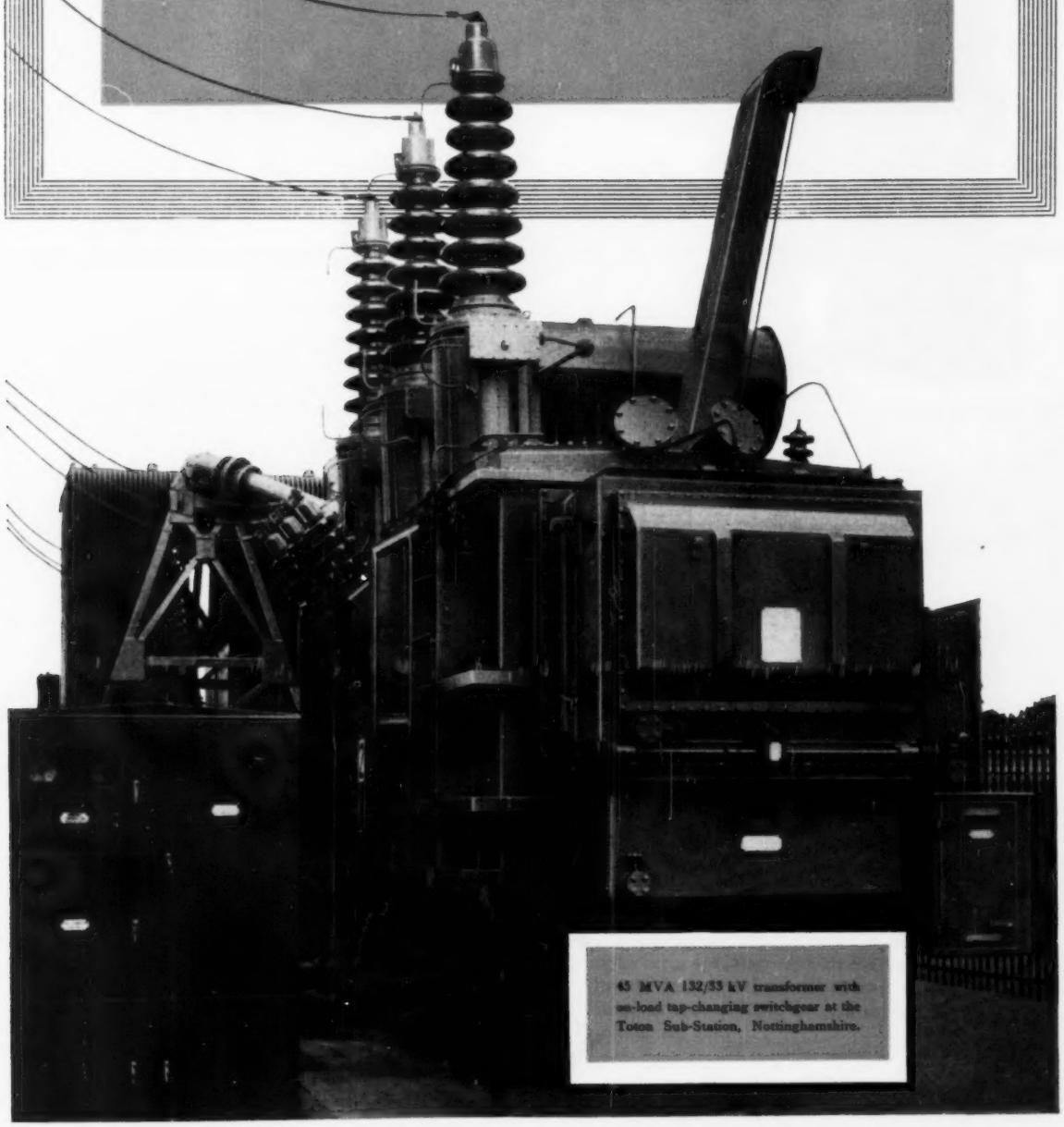
The tens of thousands of Bruce Peebles transformers in successful operation today constitute a reliable guide in selecting transformers to meet the demands of tomorrow

Bruce Peebles transformers running into millions of kVA in units up to 75 MVA have been supplied for use all over the world and much larger equipments for 275 kV service are now on order.



45 MVA 132/33 kV transformer with on-load tap-changing switchgear at the Toton Sub-Station, Nottinghamshire.

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For whatever purpose a stationary battery is required, in any capacity from 10 to 15,000 ampere-hours, there is a D.P. type specially designed to meet the need with the utmost efficiency and economy.

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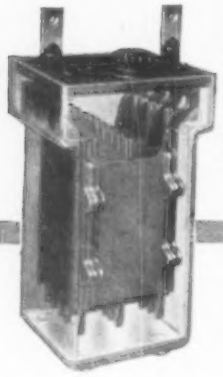

A sealed type 75 Ampere-hour D.P. cell as used for emergency lighting and power stations.

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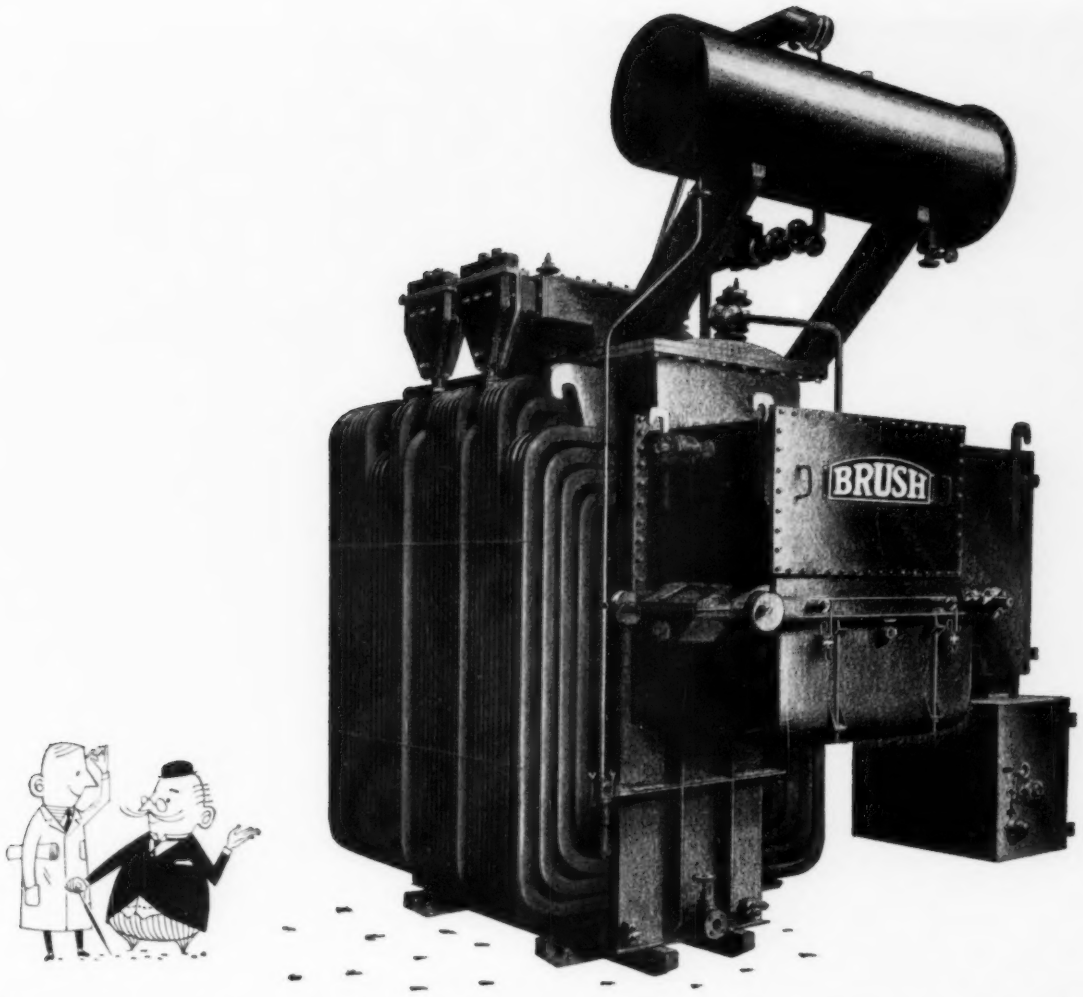

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Oh, well, sir, you see . . . Well, there's so much one can say . . .

Well then say it, man! Why Brush?

Look sir, it's like this. Brush built their first transformer in 1880. Since then they have gained a towering reputation for their consummate skill and thoroughness, for the utter dependability and the mechanical and electrical strength of their transformers. You find Brush transformer installations all over the globe—from Walsall to Wagga Wagga: from Curaçao to Christchurch—and many of them have been in service for fifty years or more.

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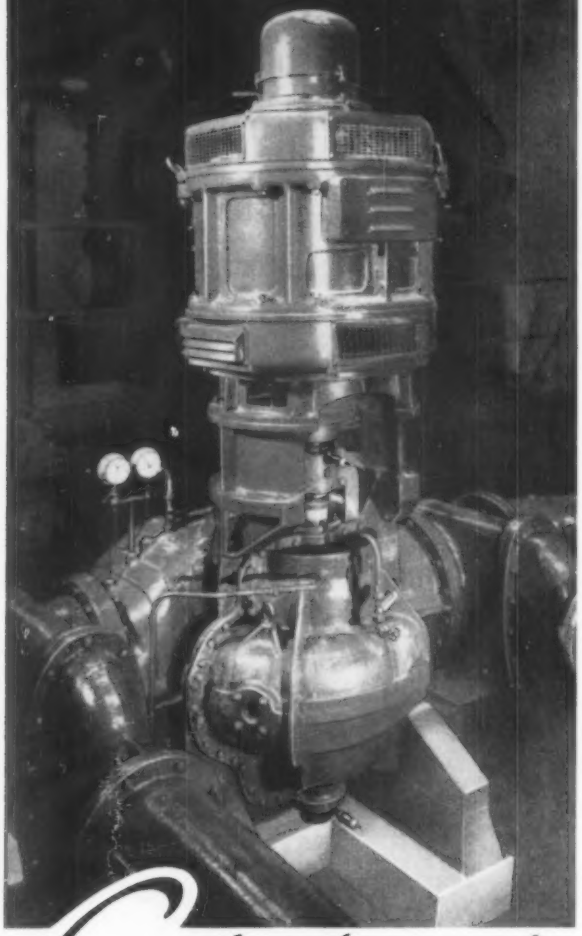

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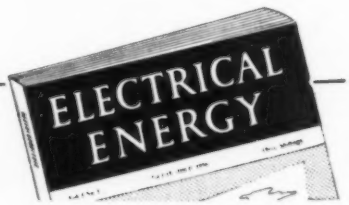

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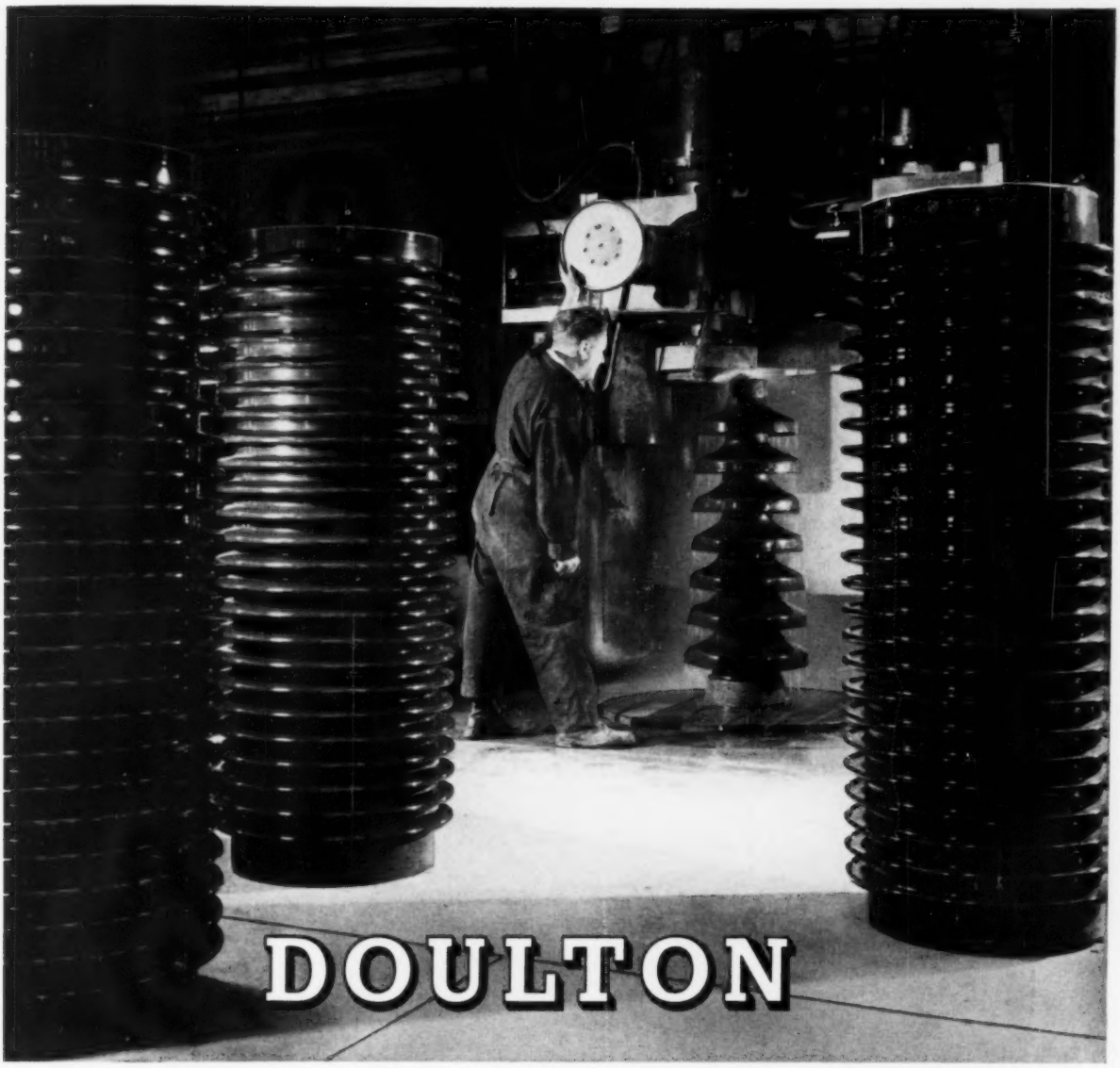

INSULATORS

A 132 kV Porcelain anti-fog cable ceiling end being ground to dimensional tolerances, as supplied to Pirelli General Cable Works Ltd. for use on C.E.G.B. contracts.

The three large 180 kV Porcelain bushings in the foreground are part of a consignment for the Canadian General Electric Co. Grinding and routine testing are the final stages before shipment to Toronto.

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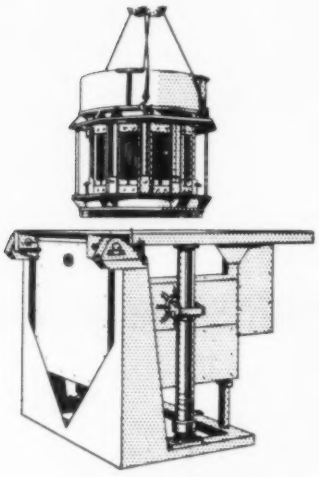

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Furnaces available from 25-lbs. to 10 tons; small models hand tilted, larger models hydraulic or motor tilted.

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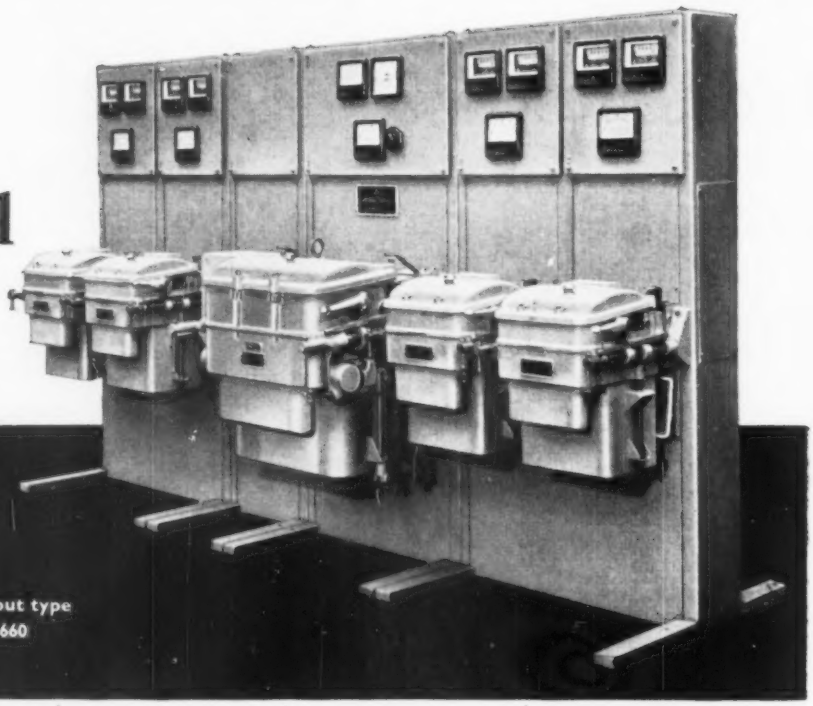

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800 ,,	45	43·3	30 ,,	600 ,,	25⅞ ,,
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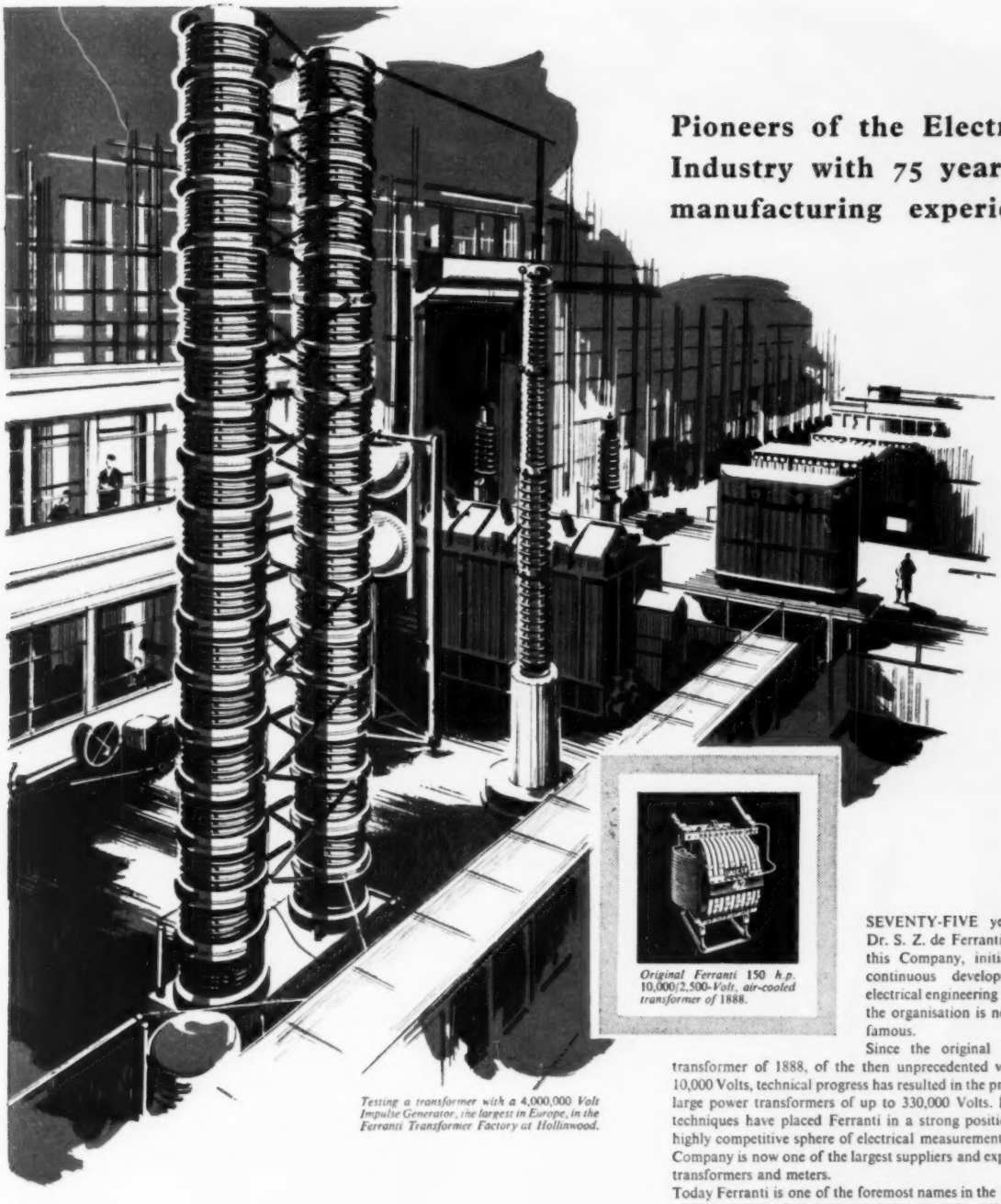

Testing a transformer with a 4,000,000 Volt Impulse Generator, the largest in Europe, in the Ferranti Transformer Factory at Hollinwood.

Original Ferranti 150 h.p. 10,000/2,500-Volt, air-cooled transformer of 1888.

Pioneers of the Electrical Industry with 75 years' manufacturing experience

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Since the original Deptford transformer of 1888, of the then unprecedented voltage of 10,000 Volts, technical progress has resulted in the present day large power transformers of up to 330,000 Volts. Improved techniques have placed Ferranti in a strong position in the highly competitive sphere of electrical measurement, and the Company is now one of the largest suppliers and exporters of transformers and meters.

Today Ferranti is one of the foremost names in the Electrical and Electronic Industries and in several well-equipped factories and laboratories, they sponsor far-reaching researches and extend the most up-to-date manufacturing facilities to many branches of Electrical Engineering and Electronics.

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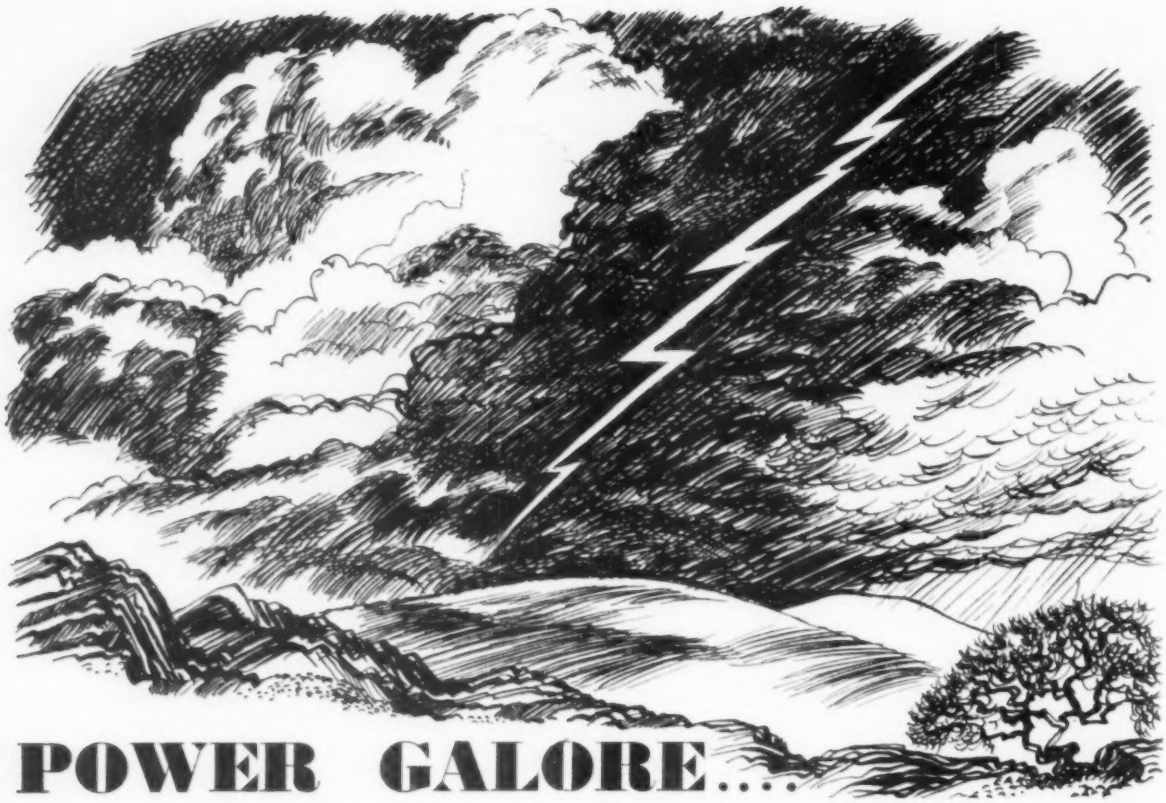


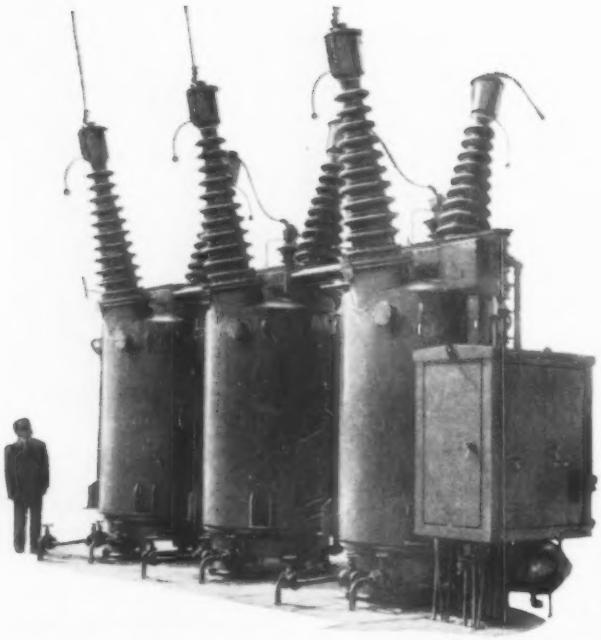
POWER GALORE....

—the electric storm represents the uncontrolled element of Electricity in all its wasted fury. Such power, properly controlled, is of immense service to mankind.

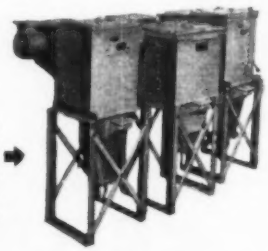
In modern electrical supply systems and efficiently performing its share of the work implied in the comprehensive term "control", is a great deal of "Ferguson Pailin" Switchgear of various types.

Among these are the bulk-oil circuit-breakers, type XOPR54 and type XOPR60, for outdoor service The XOPR60 circuit-breaker is remarkable in that it is the first circuit-breaker of its type, manufactured in Great Britain, capable of interrupting and making fault currents equivalent to 5000 MVA at 132kV. The tests to prove this rating were conducted in accordance with the requirements specified in British Standard 116 (1952) and a corresponding A.S.T.A. Certificate has been issued.

The circuit-breaker is ideally suitable for heavily interconnected systems and has been liberally designed for use under any climatic condition.



Type XOPR 60 Oil Circuit-Breaker



Another interesting unit operating at a much lower power level is the 11kV, type "OFS" fuse-switch—an adaptable design which can be connected in various arrangements with other units of the circuit-breaker and oil-switch types.

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Following the formation of the new company they've concluded an agreement for the exchange of technical information with the American Cyanamid Company—covering 25 years and this close link will be invaluable in widening their range, and accelerating technical progress.

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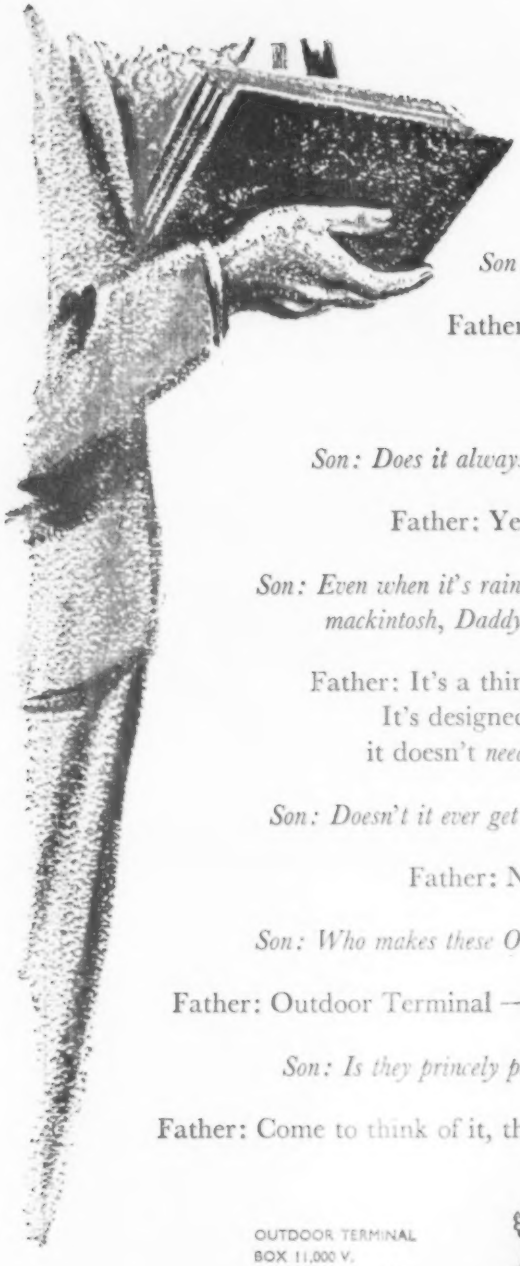


Son: What's that funny thing, Daddy?

Father: That's an electrical thing called an Outdoor Terminal Box, son.

Son: Does it always live out of doors, then?

Father: Yes, son.

Son: Even when it's raining? Has it got a mackintosh, Daddy?

Father: It's a thing, not a person. It's designed that way — it doesn't *need* a mackintosh.

Son: Doesn't it ever get a cold?

Father: No!

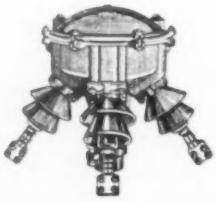
Son: Who makes these Outlaw Terminus Boxes?

Father: Outdoor Terminal — Henley's, principally.

Son: Is they princely people then?

Father: Come to think of it, they is . . . are, really!

OUTDOOR TERMINAL
BOX 11,000 V.
Send for Catalogue 33



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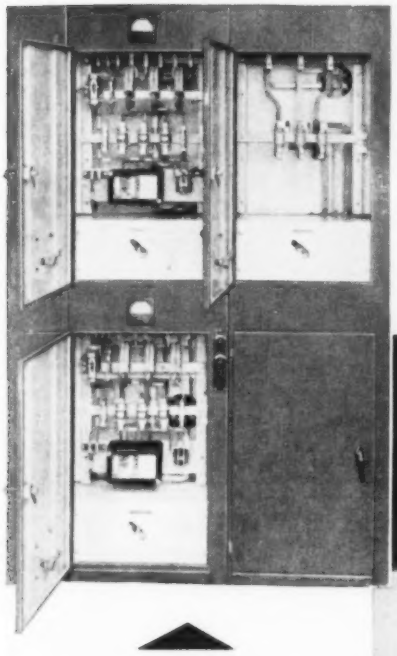
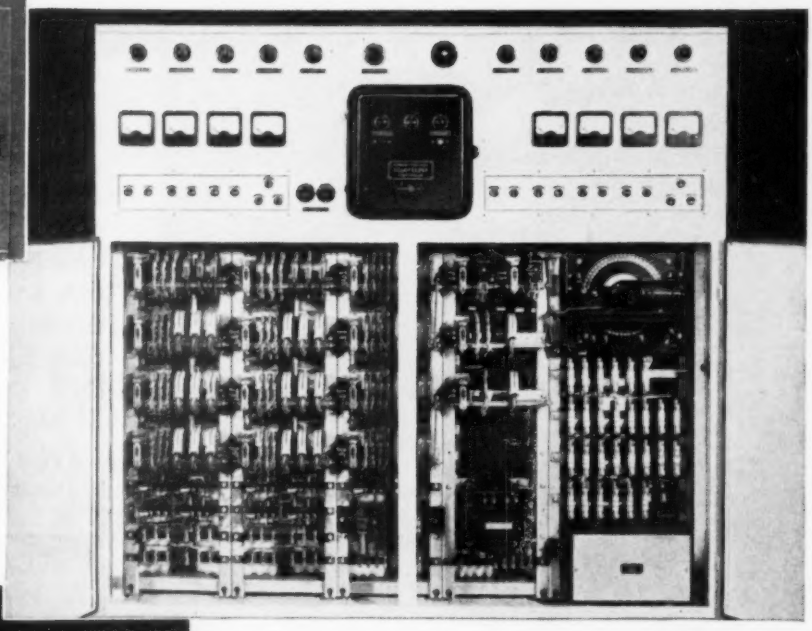
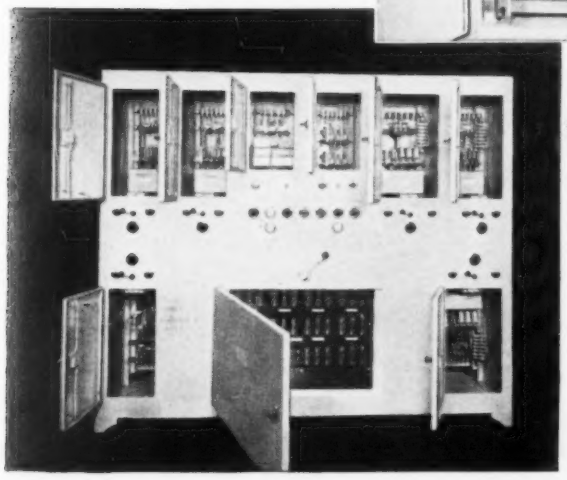


Two section, two-tier panel, one of a series supplied to a well-known paper manufacturing firm.



Special purpose panel supplied for the control of an automatic brick-making plant.



Multi-motor control panel with individual compartment and isolation for each motor starter, supplied to a large synthetic fibre manufacturing concern.

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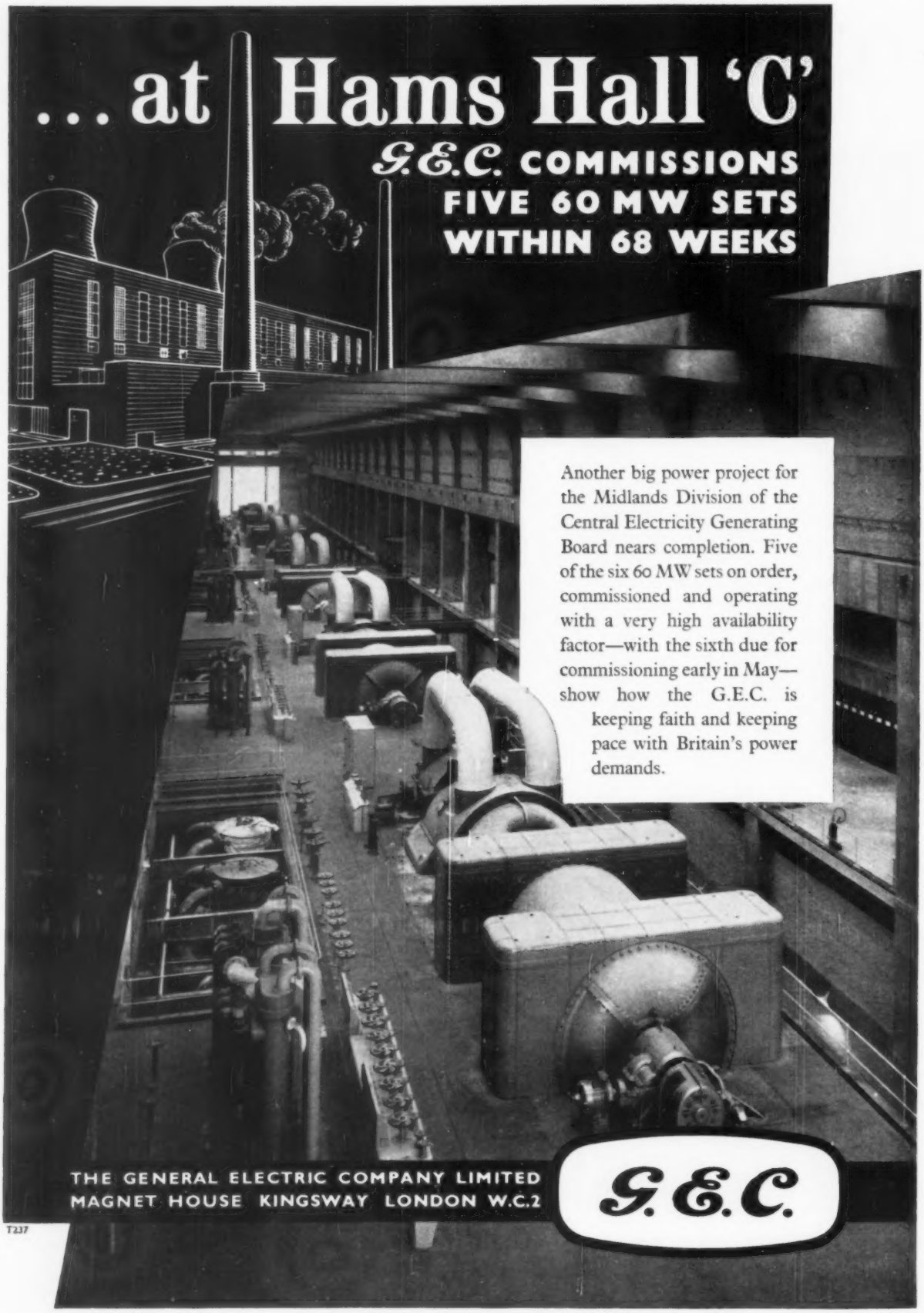

Another big power project for the Midlands Division of the Central Electricity Generating Board nears completion. Five of the six 60 MW sets on order, commissioned and operating with a very high availability factor—with the sixth due for commissioning early in May—show how the G.E.C. is keeping faith and keeping pace with Britain's power demands.

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The illustrations show coil winding, and the core and winding assembly of a typical 60 MVA 132/33 kV Hackbridge transformer.

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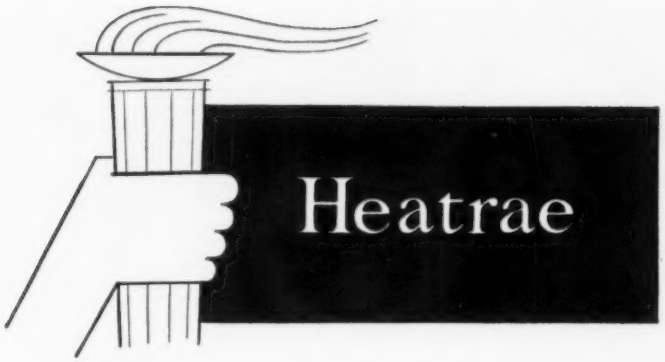

Electric Air Heaters for Industry

FIG. 1

For many years Heatrae Limited have designed and manufactured Air Heaters to meet a large variety of industrial requirements. Two typical types are here illustrated.

FIG. 2

Fig. 1 shows a Drum type Air Heater suitable for the higher pressures, and working temperatures up to, and occasionally exceeding, 600° F. The Control Panels are supplied as self-contained units for separate fixing, or can be embodied in the main construction if preferred. These heaters are often supplied for use in hazardous positions where Buxton Certified Flameproof Equipment is required.

Fig. 2 shows a very compact form of Air Heater of rectangular construction, suitable for low pressure working. These heaters are for insertion in duct runs. More detailed information on the various types of Air Heaters and their application is given in Heatrae Catalogue, Section CAE. Copies will gladly be sent on request.

Your enquiries are invited

Heatrae

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HEATRAE LIMITED NORWICH

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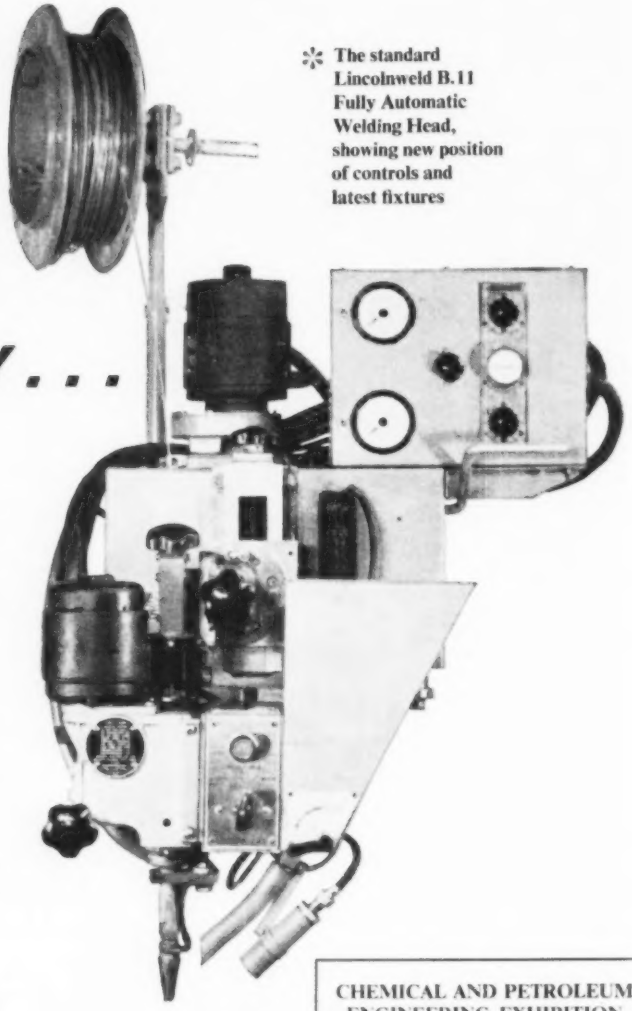

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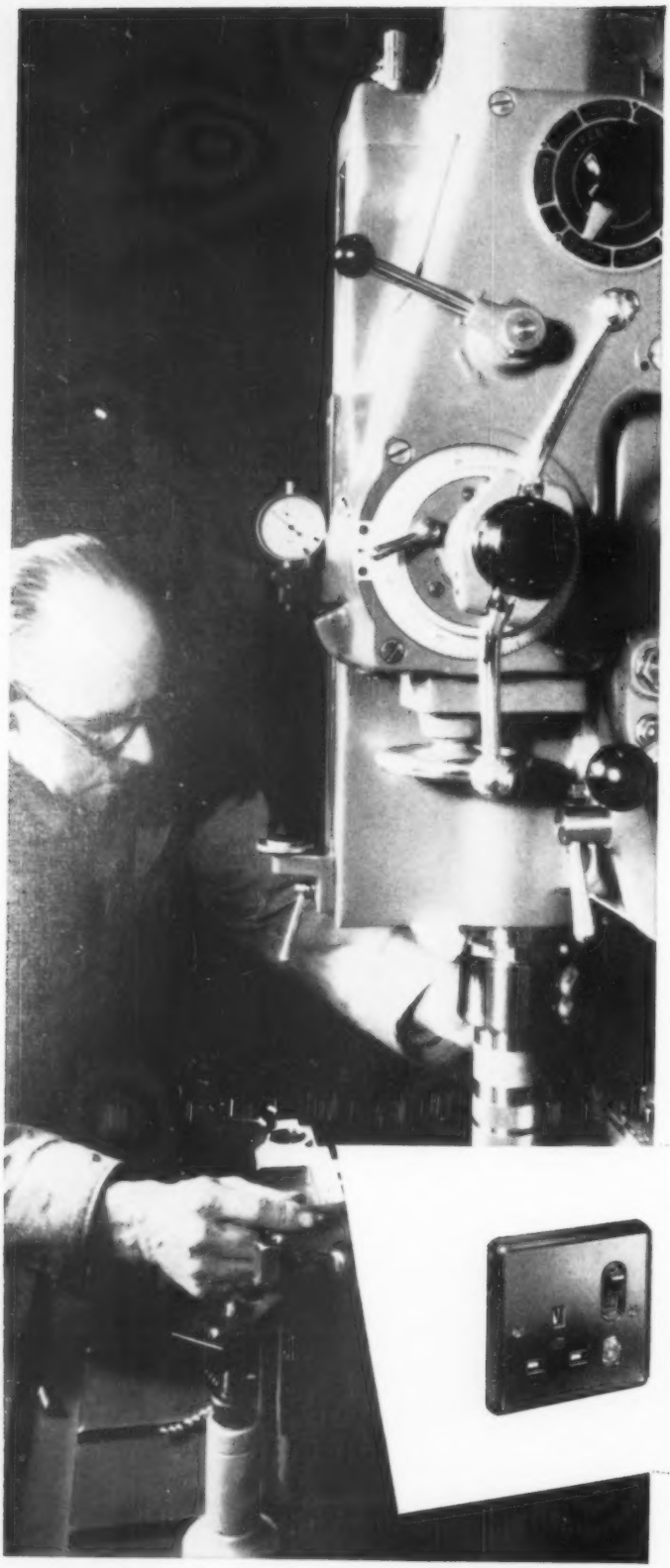

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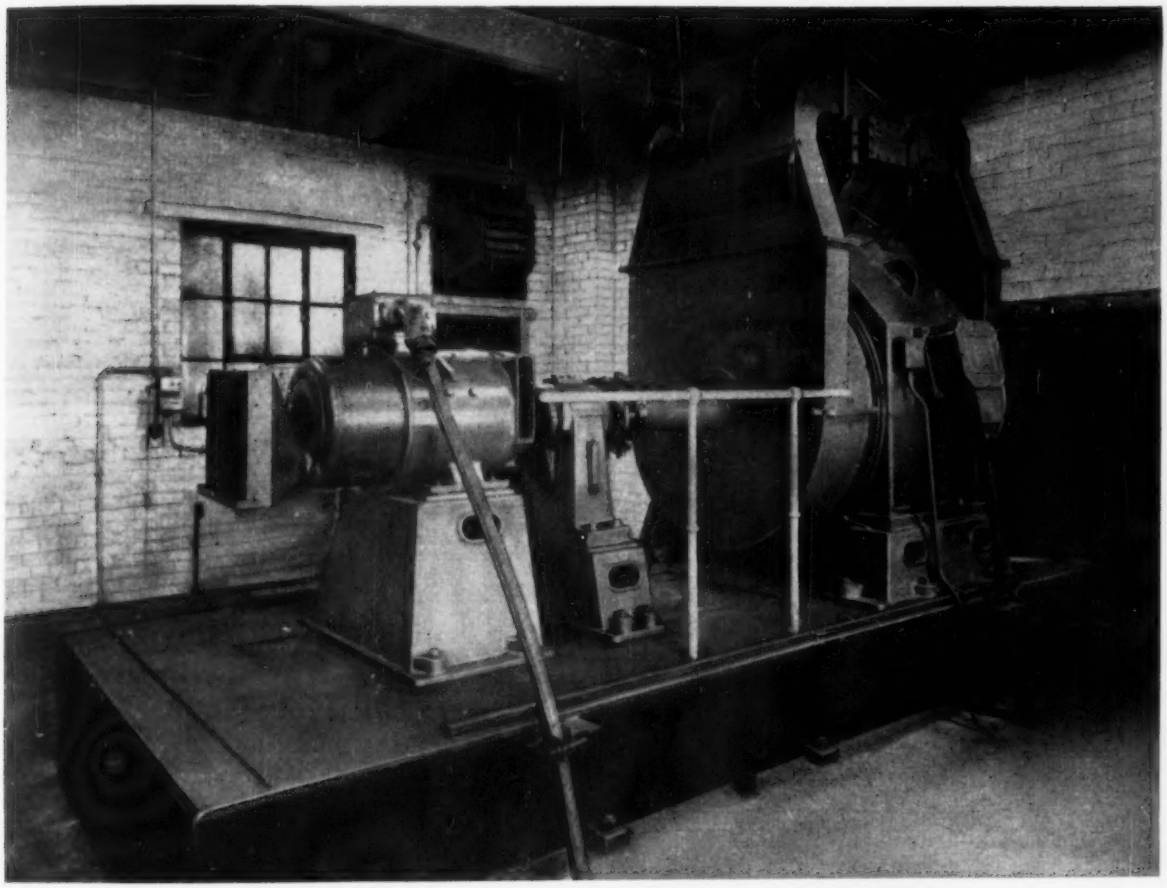

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812

A Mather & Platt water-cooled duct-ventilated synchronous motor operating at unity power factor driving a fan in the sinter plant of a large iron ore plant. It is rated at 1050 b.h.p., 825 kVa, 2750 v., 750 r.p.m. and is direct-on started taking a low starting current. Two such motors have been supplied.

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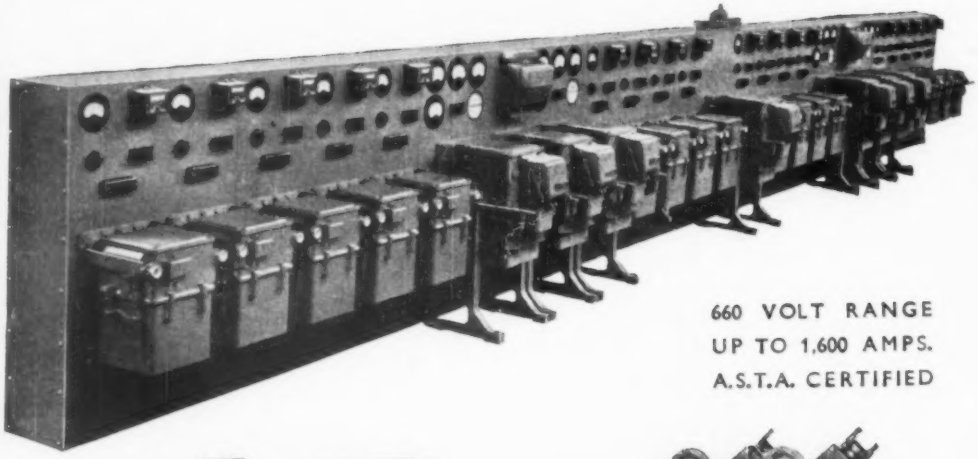

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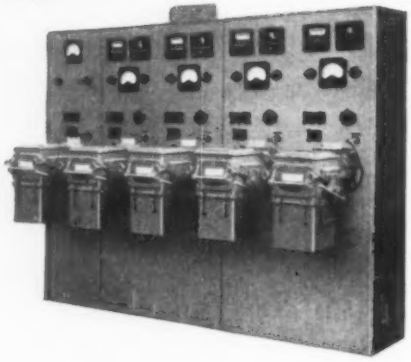

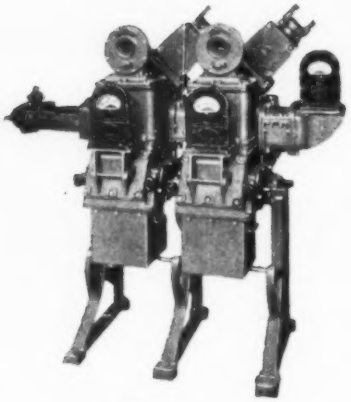

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UP TO 400 AMPS.

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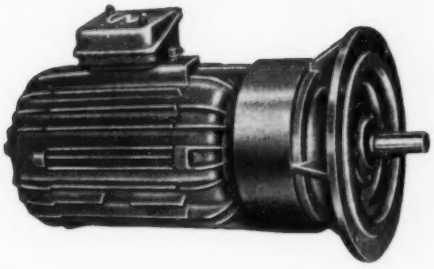

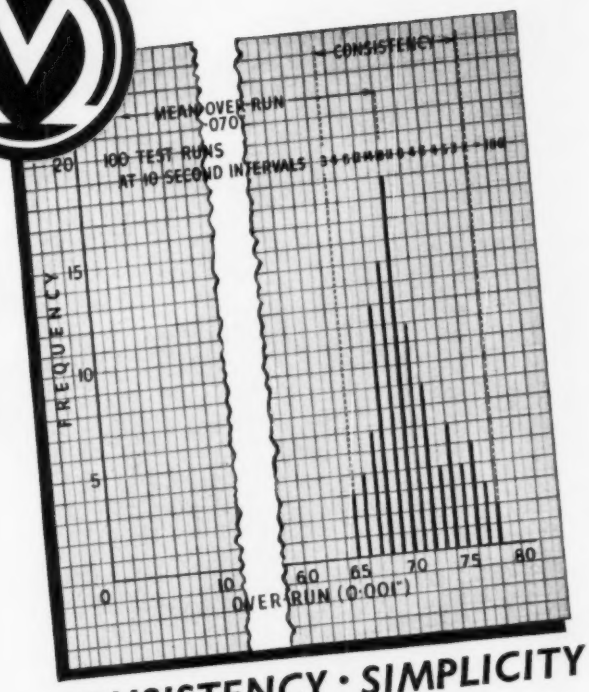

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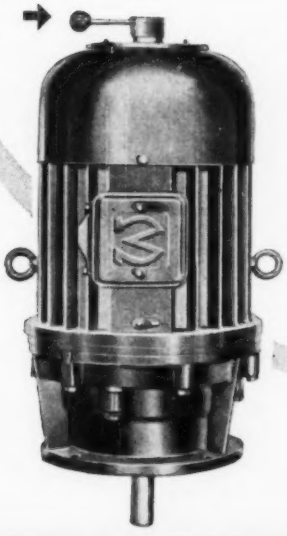
Hand Operated Brake Release supplied when requested



British Patent No. 718728 covers A.C. Motor providing Actuating Thrust. British Patent Application No. 36521/55 covers Mechanical Clutch/Brake

Outstanding features of ***The Mawdsley A.C. Stop Clutch Motor***

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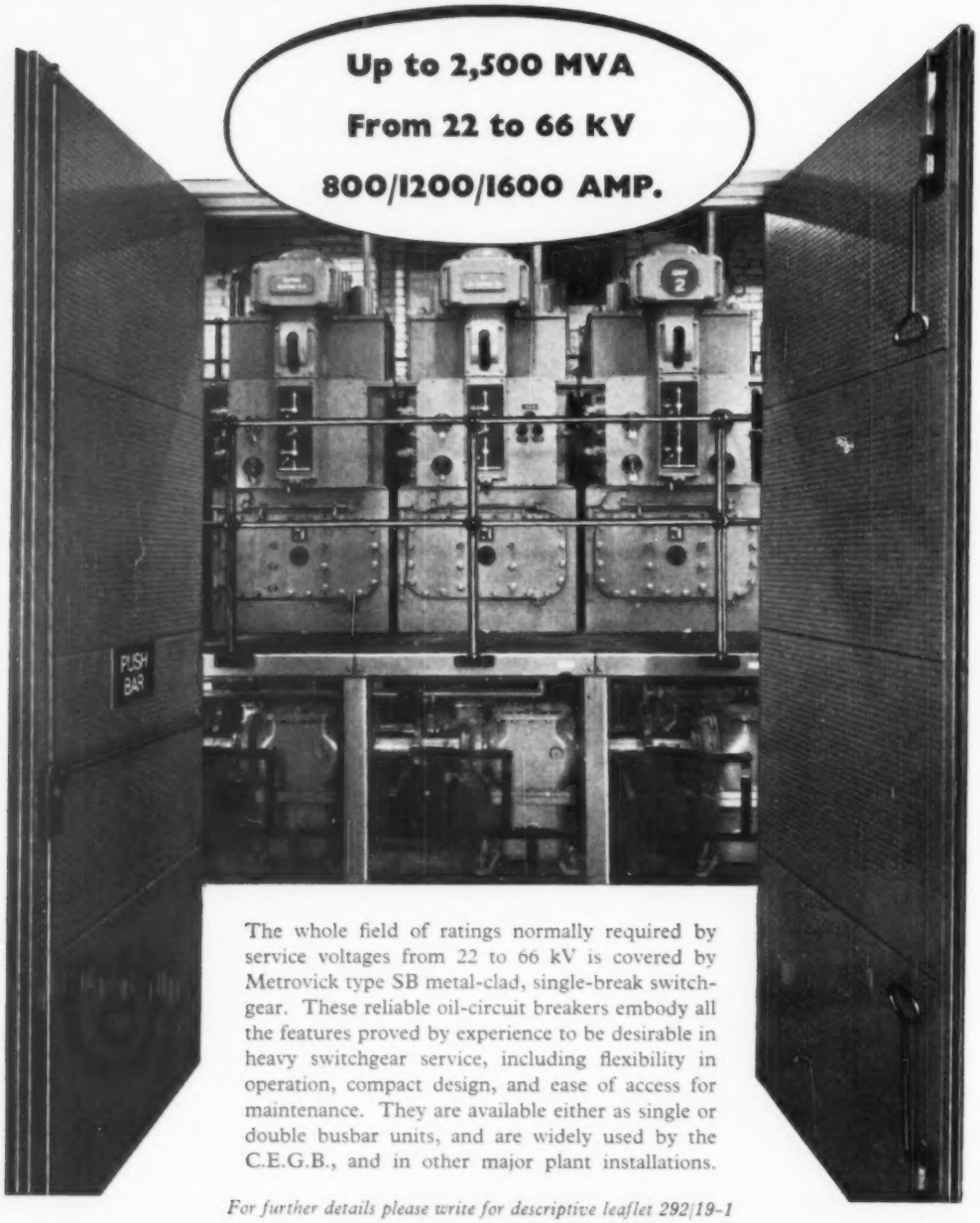
FOR INDOOR SERVICE

Up to 2,500 MVA

From 22 to 66 kV

800/1200/1600 AMP.



The whole field of ratings normally required by service voltages from 22 to 66 kV is covered by Metrovick type SB metal-clad, single-break switchgear. These reliable oil-circuit breakers embody all the features proved by experience to be desirable in heavy switchgear service, including flexibility in operation, compact design, and ease of access for maintenance. They are available either as single or double busbar units, and are widely used by the C.E.G.B., and in other major plant installations.

For further details please write for descriptive leaflet 292/19-1

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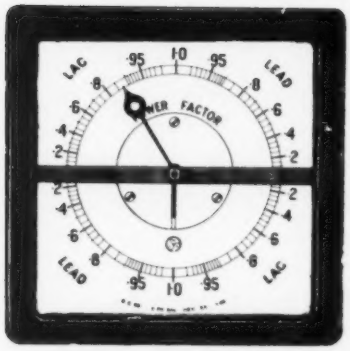

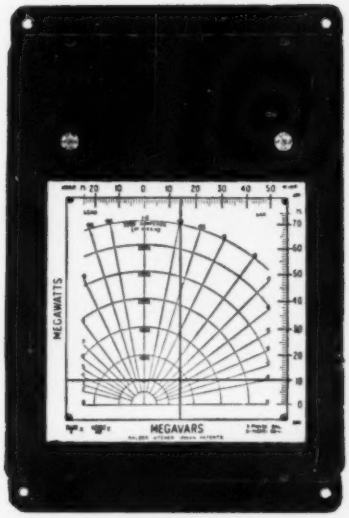

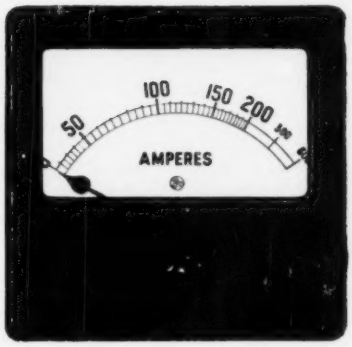

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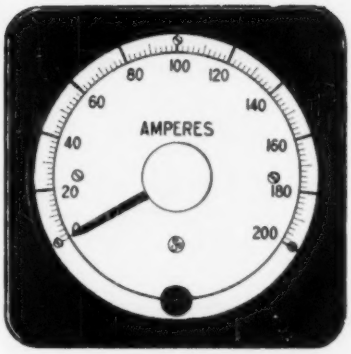
The *only* instrument to give simultaneous readings of Megawatts, Megavars, Amperes and Power Factor of the three-phase system in which it is connected. It shows also whether Power is being "Exported" or "Imported." Indication is by two pointers moving at right angles and in straight lines over a common dial. The Megawatt, Megavar and Ampere scales are each 6 ins. long.



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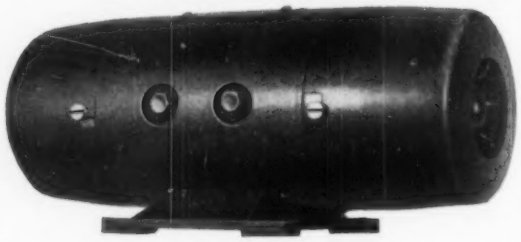

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Up to 100 watts output, weight 5¼ lb.

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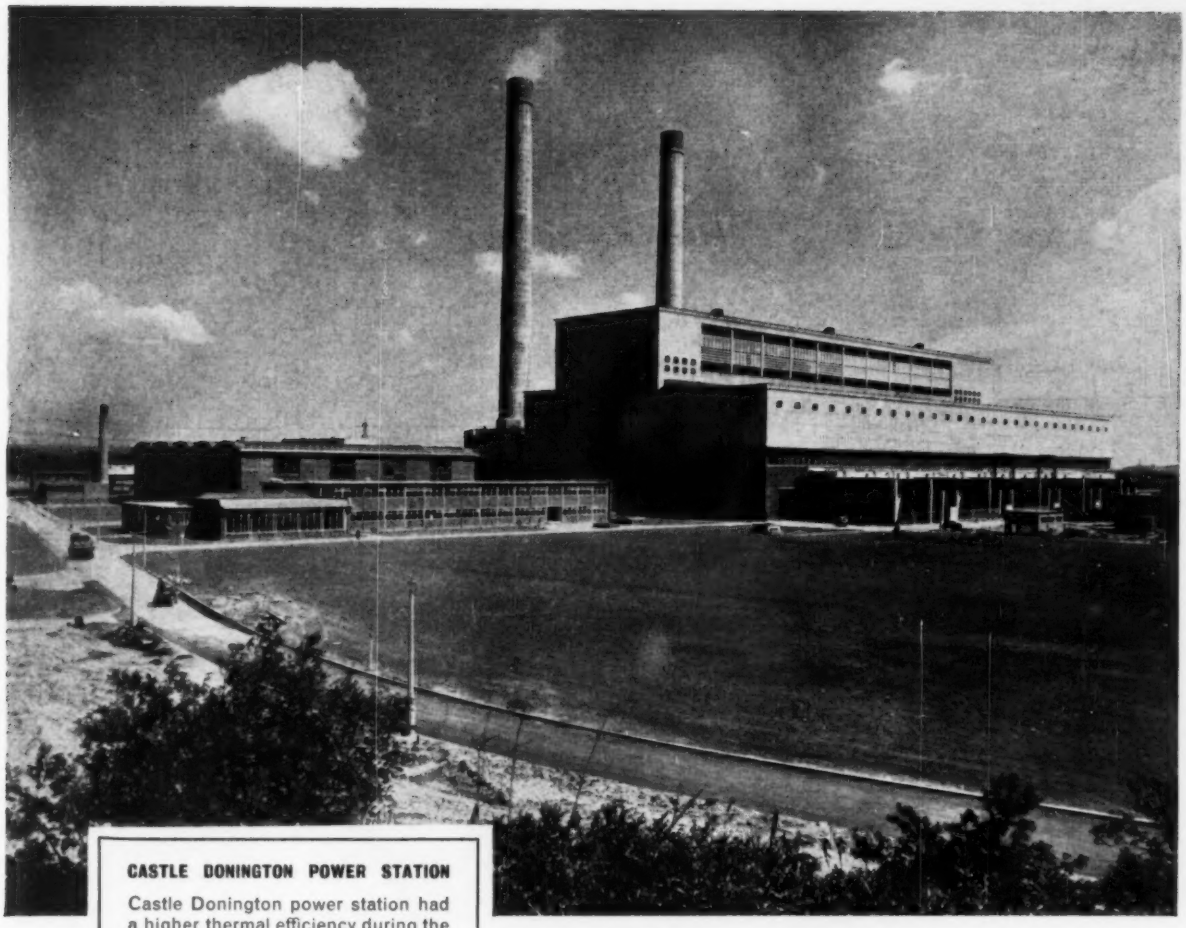

CASTLE DONINGTON POWER STATION

Castle Donington power station had a higher thermal efficiency during the year ended 31st Mar., 1957, than any other power station in Great Britain. The motors driving the auxiliaries are protected by P & B Golds relays in this and many other power stations of the Central Electricity Generating Board.

C·E·G·B chose P&B Golds protection

P & B Relays give full protection for motors with any starting periods or currents under extremes of ambient temperature.
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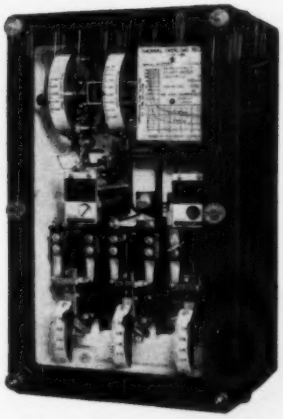

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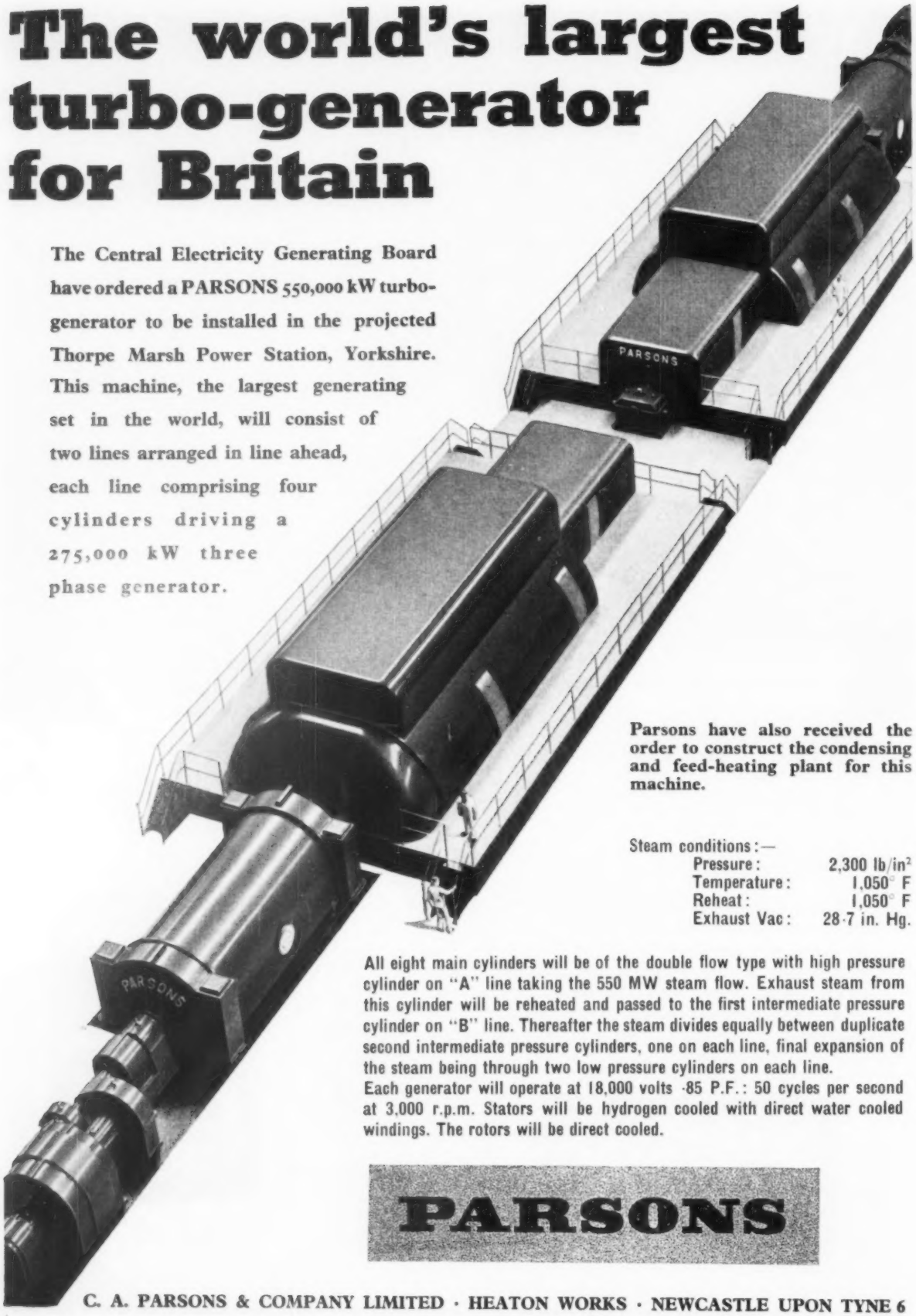
The world's largest turbo-generator for Britain

The Central Electricity Generating Board have ordered a PARSONS 550,000 kW turbo-generator to be installed in the projected Thorpe Marsh Power Station, Yorkshire. This machine, the largest generating set in the world, will consist of two lines arranged in line ahead, each line comprising four cylinders driving a 275,000 kW three phase generator.



Parsons have also received the order to construct the condensing and feed-heating plant for this machine.

Steam conditions:—

Pressure:	2,300 lb/in²
Temperature:	1,050° F
Reheat:	1,050° F
Exhaust Vac:	28·7 in. Hg.

All eight main cylinders will be of the double flow type with high pressure cylinder on "A" line taking the 550 MW steam flow. Exhaust steam from this cylinder will be reheated and passed to the first intermediate pressure cylinder on "B" line. Thereafter the steam divides equally between duplicate second intermediate pressure cylinders, one on each line, final expansion of the steam being through two low pressure cylinders on each line.
Each generator will operate at 18,000 volts ·85 P.F.: 50 cycles per second at 3,000 r.p.m. Stators will be hydrogen cooled with direct water cooled windings. The rotors will be direct cooled.

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Glass Fibre Flat Sheet is

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A general purpose fine weave glass cloth polyester laminate suitable for electrical and mechanical purposes.

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A general purpose coarse weave glass cloth polyester laminate, generally similar to Grade 83/AE but for use in greater thicknesses.

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A fine weave glass cloth epoxide resin laminate having improved electrical and mechanical strength.

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A coarse weave glass cloth epoxide resin laminate, generally similar to Grade 84/AE but for use in greater thicknesses.

GRADE 81/AE *Phenolic/Fine Weave*
A fine weave glass cloth phenolic resin laminate with outstanding resistance to chemicals and good electrical properties.

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A fine weave glass cloth melamine resin laminate which is flame retardant, has good electrical properties and conforms to Def 5000, spec. M.1.

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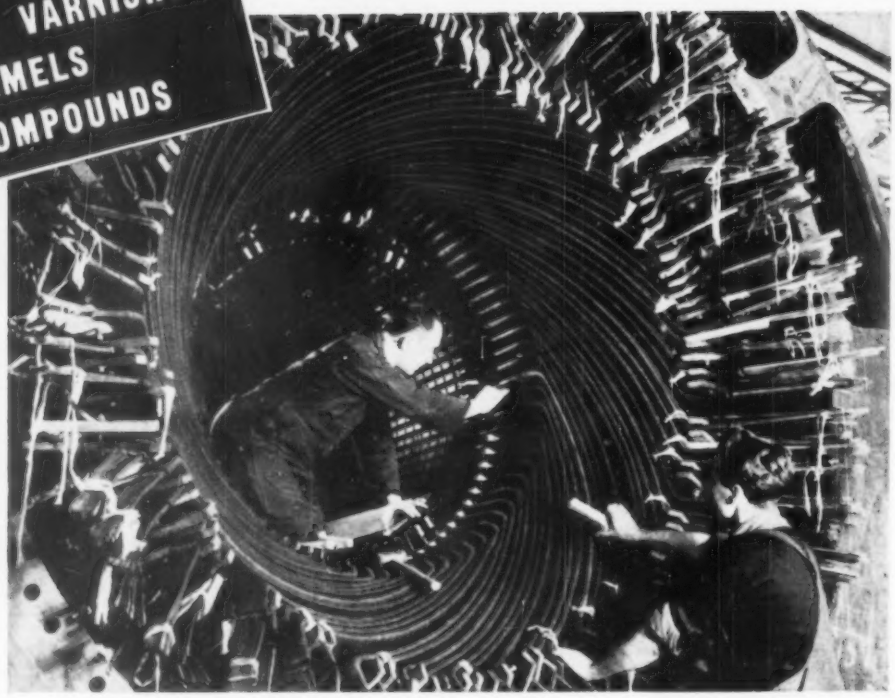

A Stator under construction

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We are constantly developing Special Varnishes to meet the many and varied requirements of the Electrical Industry. The tendency has been to concentrate on the development of Varnishes utilising Synthetic Resins. The advent of these Synthetic Types of Insulating Varnishes which have been developed by constant research over many years in our Chemical, Electrical and Physical Laboratories has enabled us to produce Insulating Varnishes to meet the most exacting requirements set by the Electrical Industry, thereby maintaining the high reputation and standard of 'MINERVA' Insulating Products.

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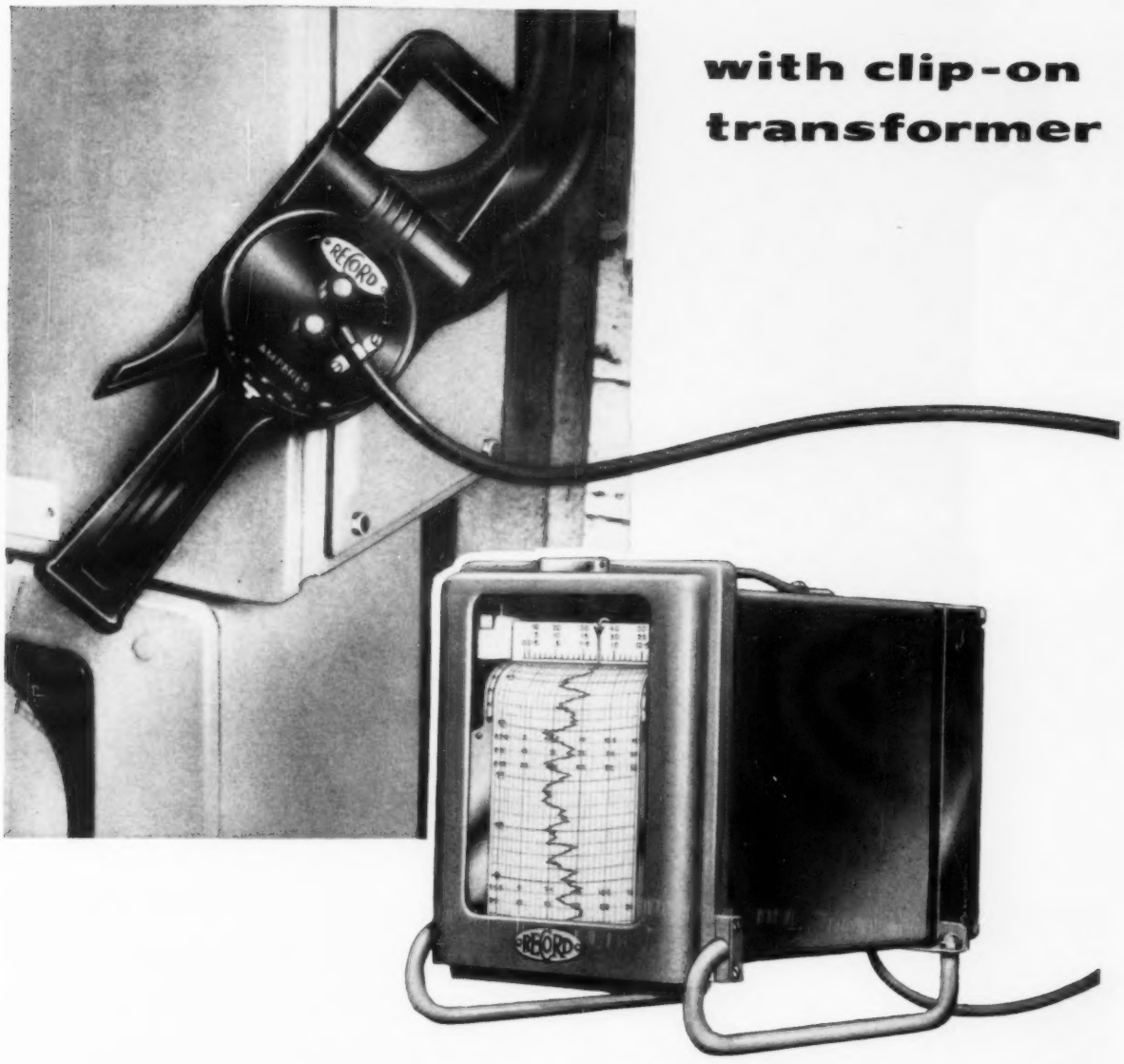
with clip-on transformer



The combination shown provides 7 current ranges up to 600A.

In addition the Recorder is provided with self-contained voltage ranges of 150, 300 and 600V. The whole forms an easily transportable Universal A.C. Recorder which is accurate, responsive and robust. Send for details.

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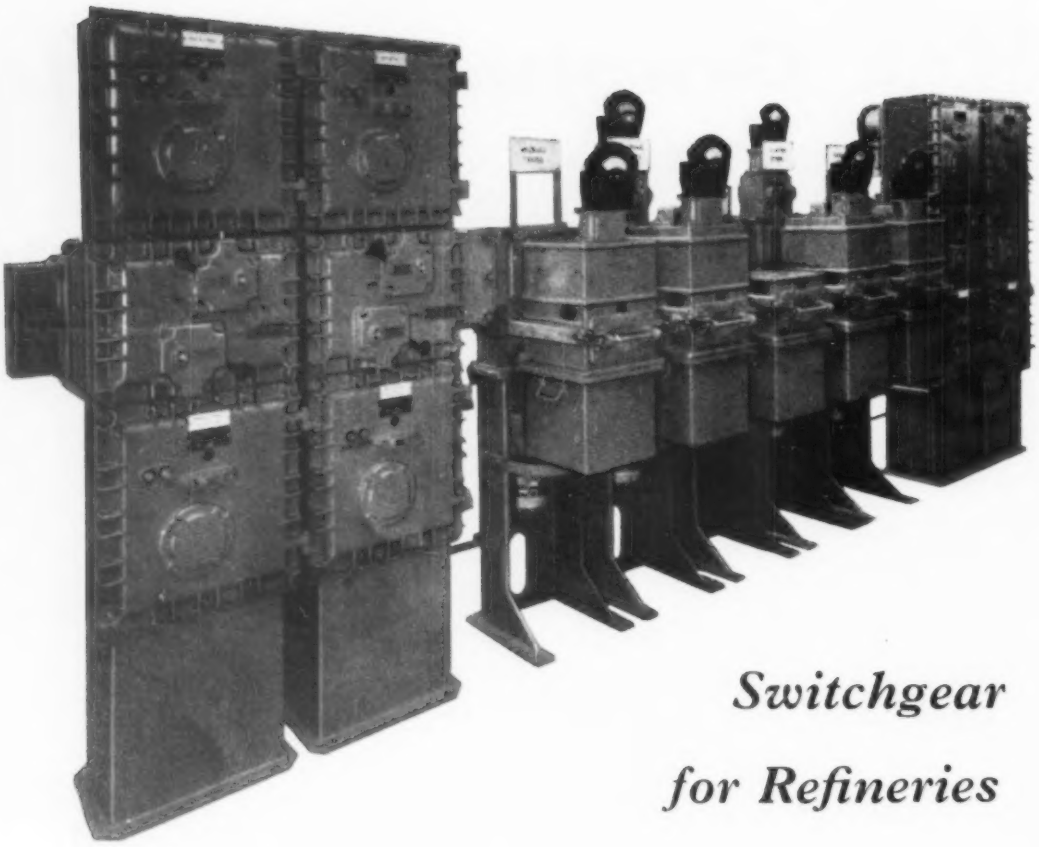

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for Refineries

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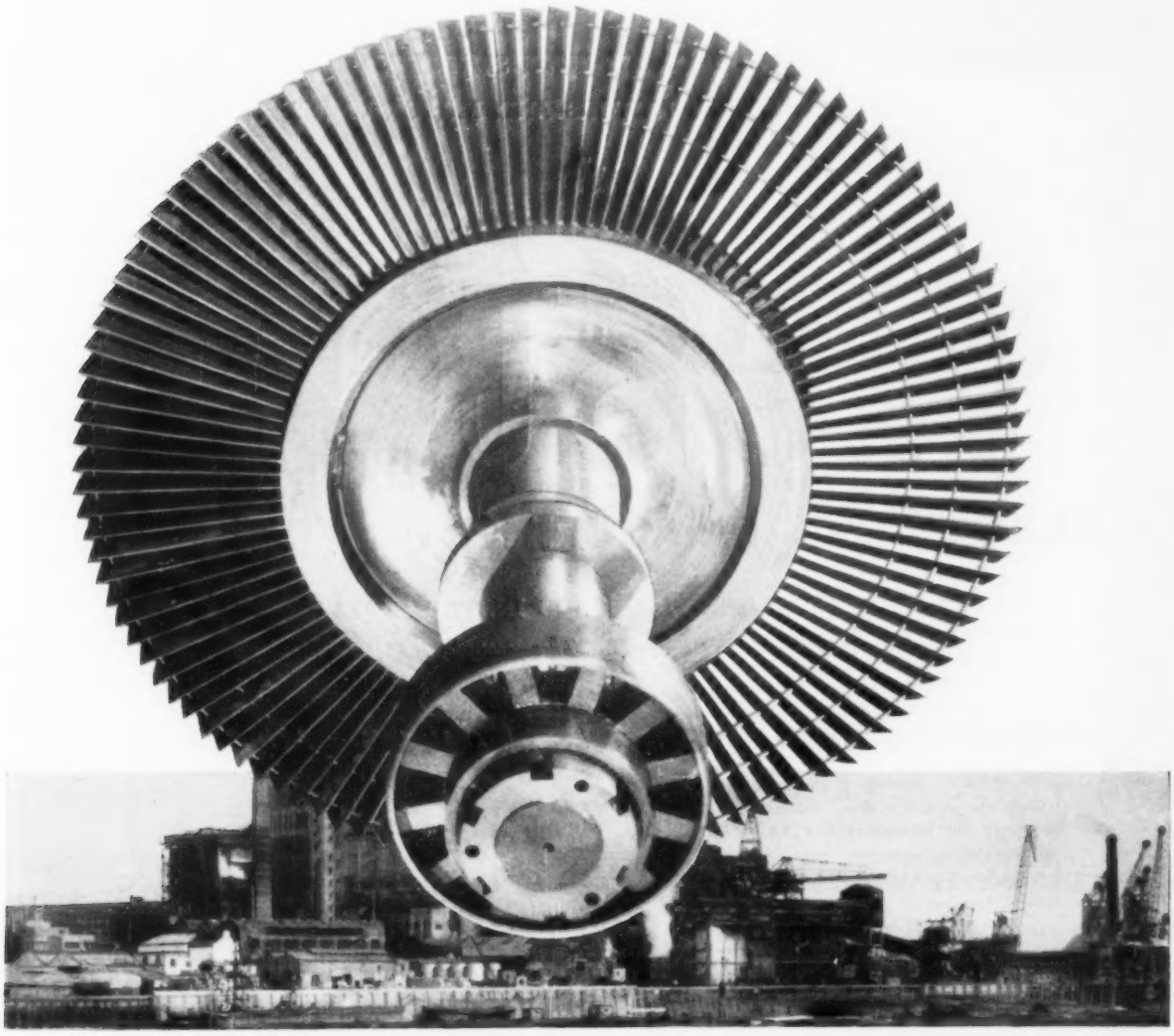

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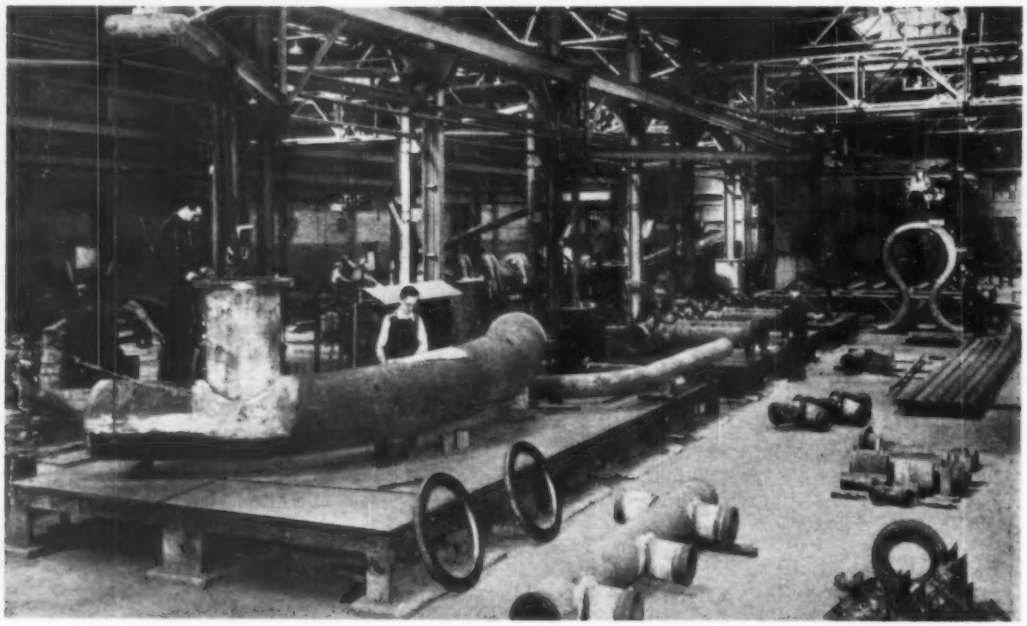
AND MANIPULATED PIPEWORK
FOR NUCLEAR POWER STATIONS



Manipulated high pressure pipework being assembled at Stewarts and Lloyds' Tollcross works. The branch pipe on the marking-off table in the foreground is for Chapelcross nuclear power station.

Stewarts and Lloyds have already contributed substantially to the construction of Britain's new nuclear power stations, in which large quantities of steel tubes and manipulated pipework are required.

Contracts in hand include material to be supplied to all nuclear power stations now under construction.

Stewarts and Lloyds design, manufacture and install pipework for all types of industrial plants.

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GLASGOW · BIRMINGHAM · LONDON

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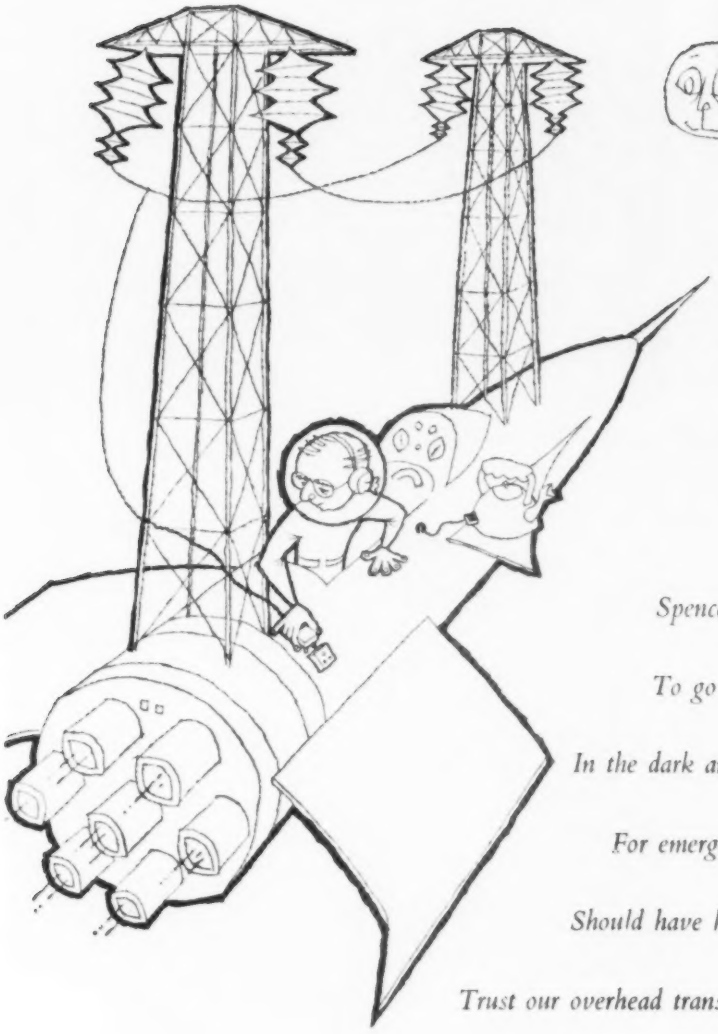

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* *SPENCER'S COPPER STRAND AND ALUMINIUM CONDUCTORS are being used for the carrying of electricity on overhead transmission lines and in many electrification schemes at present being carried out in the United Kingdom and overseas.*

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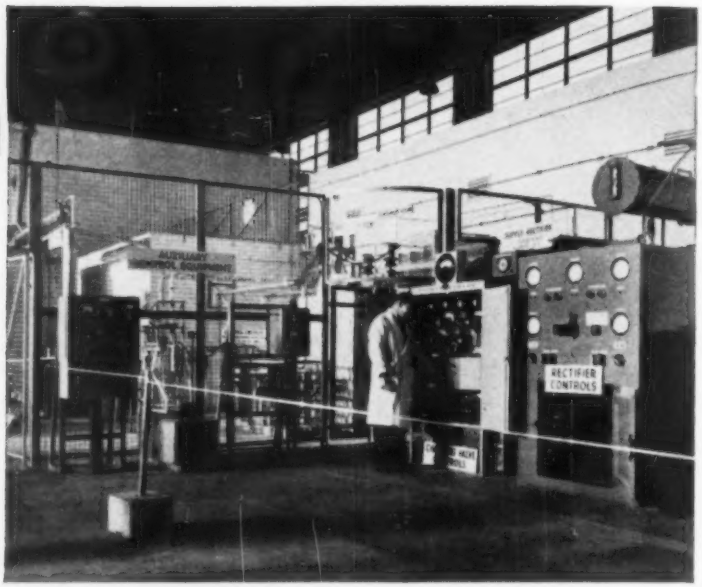
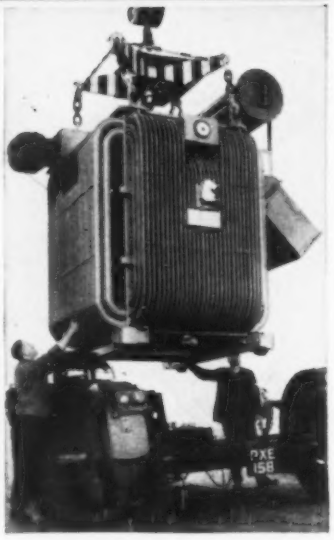
Power FOR Zeta



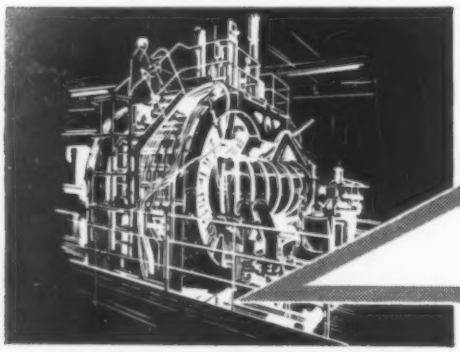
Standard Telephones and Cables Limited offer their congratulations to the U.K.A.E. physicists and engineers on the successful completion of their initial researches into controlled thermonuclear reaction. In the design and supply of the 26kV D.C. Power Plant used to start nuclear fusion, S.T.C. engineers were proud to be associated with this venture.



ZETA POWER PLANT, HARWELL. S.T.C. Equipment included the control cubicle on the right and the oil-immersed rectifier equipment behind the open cubicle. The Rectifier Division also supplied the 24kV H.T. Transformer and Supply Regulating Transformer. SenTerCel *selenium rectifiers are used in the saturable reactor.*

The 26kV 4A SenTerCet *Rectifier Equipment being loaded at the S.T.C. Rectifier Division factory for transit to Harwell.*

THE ZETA TORUS. Power from the SenTerCet *equipment is discharged via condensers into the primary of the pulse transformer. The ionized deuterium gas in the inner tube forms the secondary of the transformer. Current of the order of 200 000 amperes is induced to start nuclear fusion.*



SenTerCet

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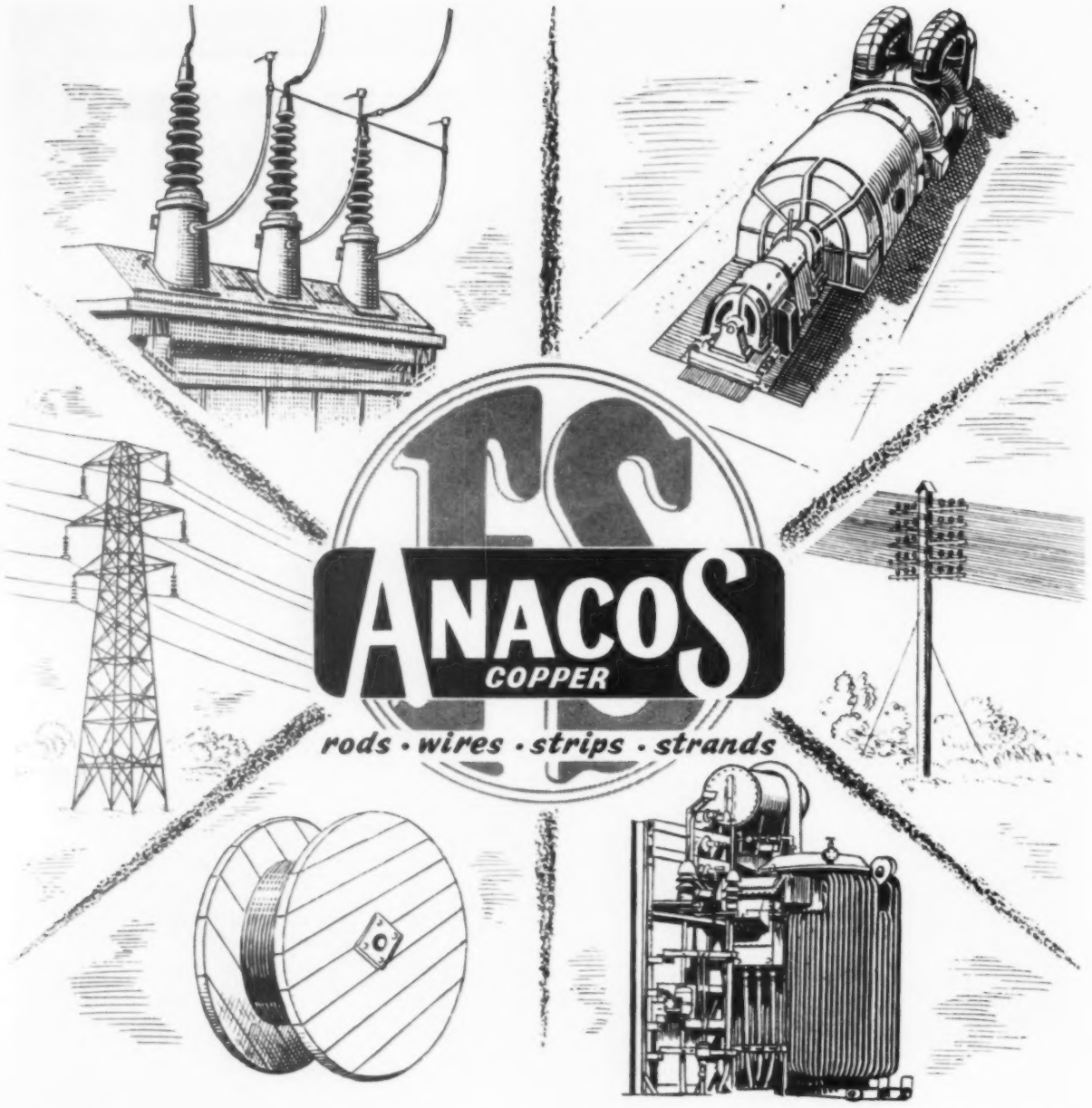

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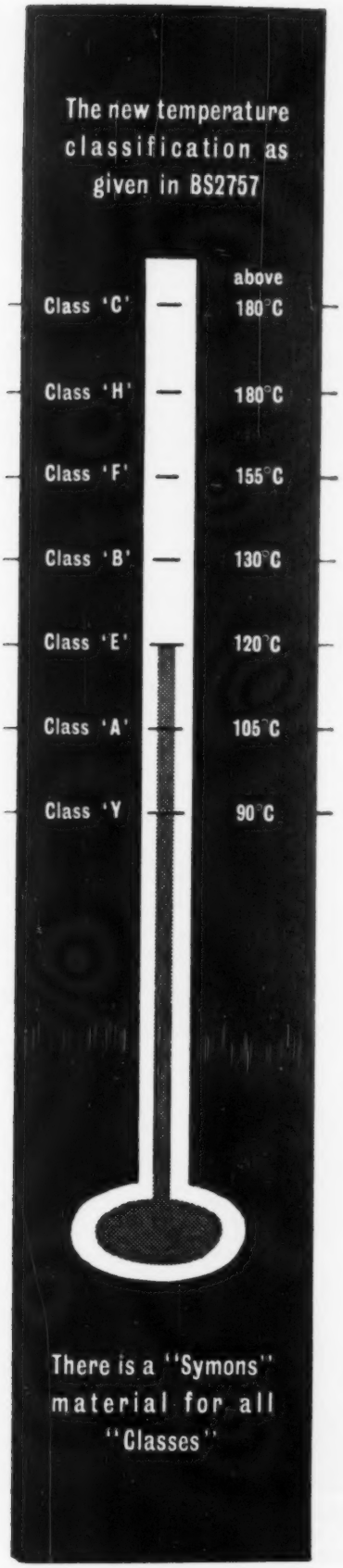
The new temperature classification as given in BS2757
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Class 'H' — 180°C
Class 'F' — 155°C
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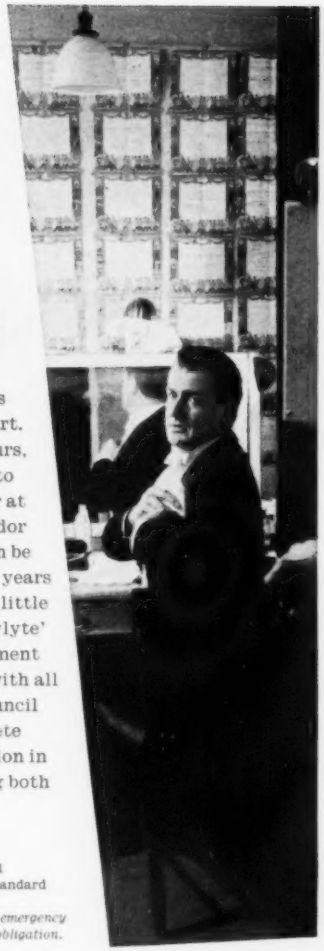

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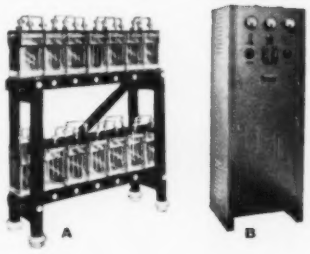
Please send for Publications Nos. 90, 91 and 92, which give full details of the standard range of 'Safetylyte' Equipment. *Comprehensive specifications for special emergency lighting installations prepared without obligation.*



A

B

A *Double-tier stand holding a typical battery of 14 Tudor sealed-type cells as used with 'Safetylyte' emergency lighting equipment.*

B *'Safetylyte' Major charging and control cubicle.*

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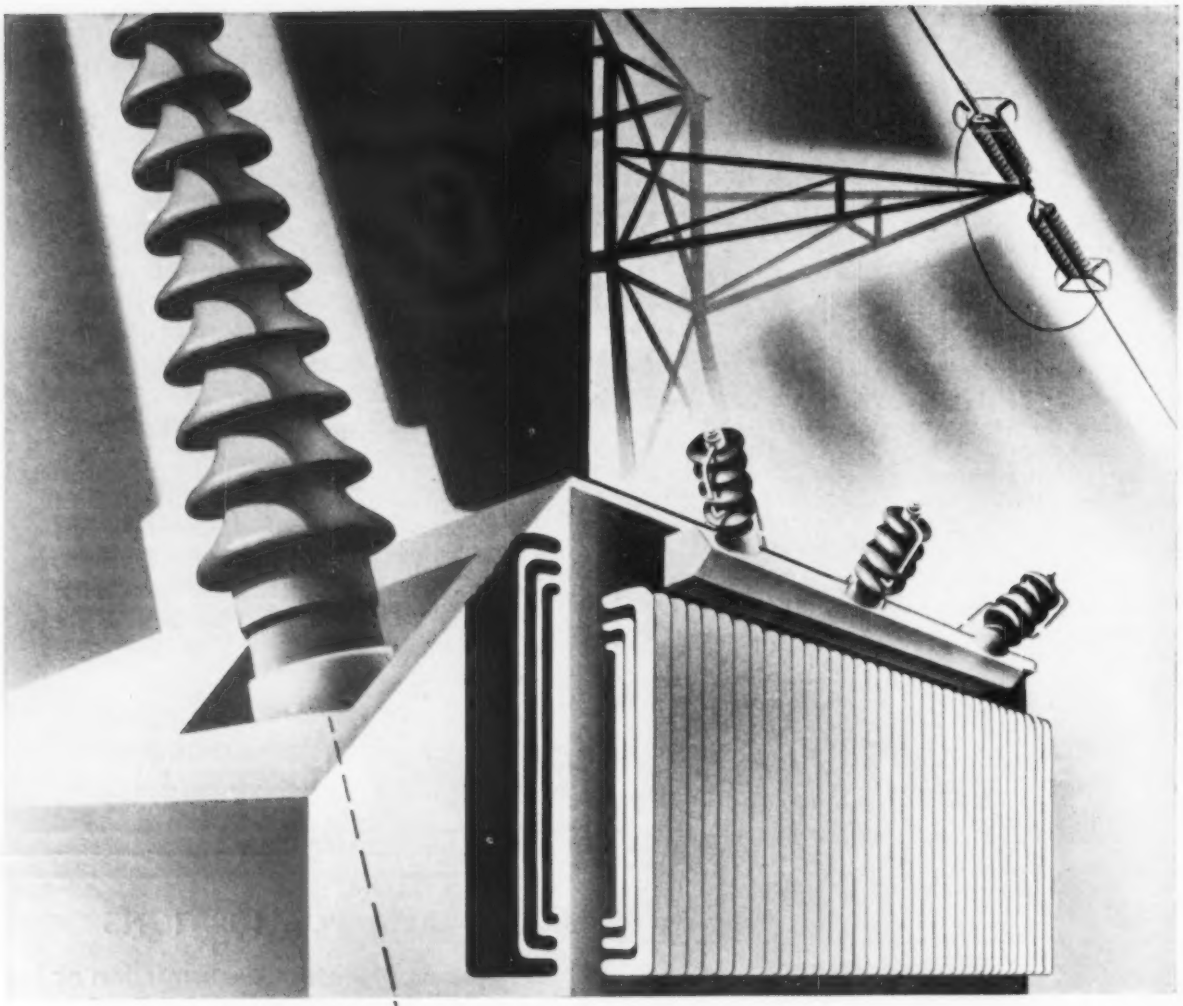

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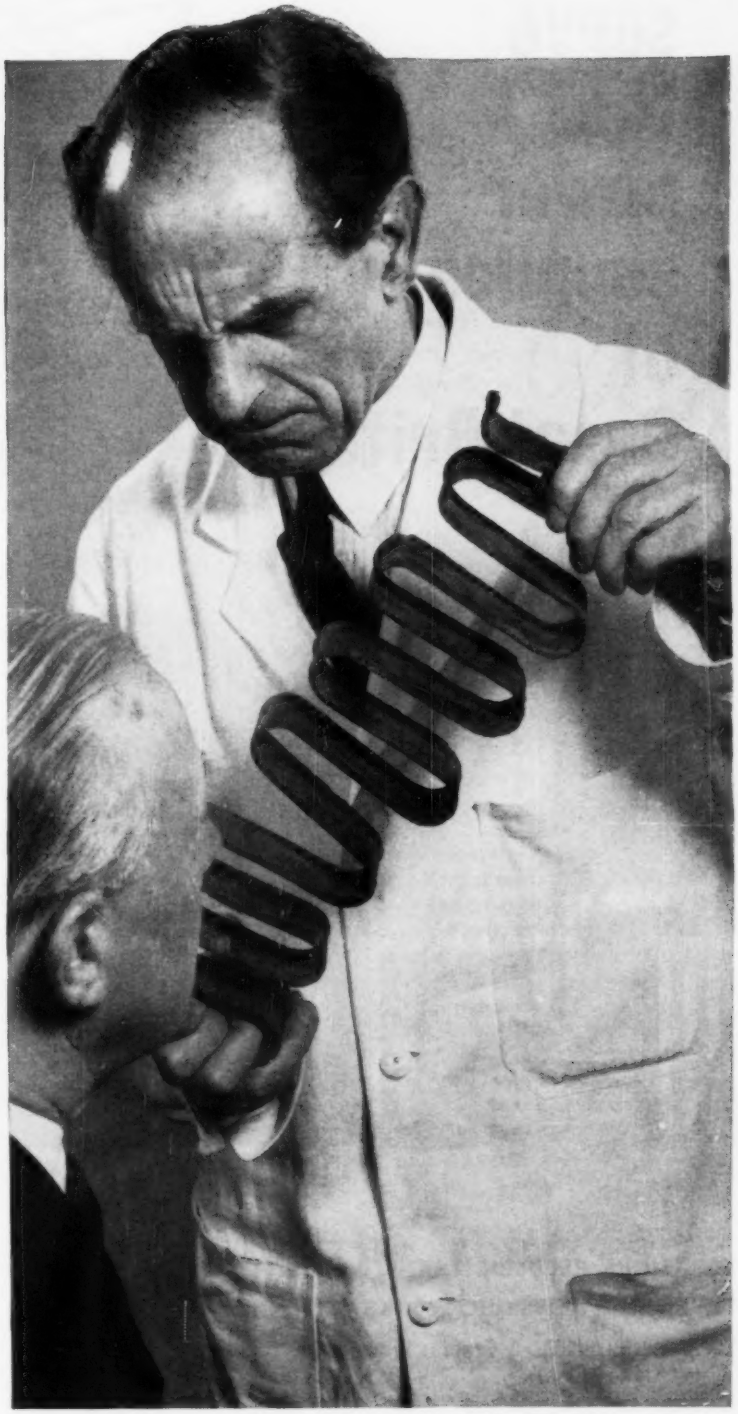
Mr. Finch is forbidding when he's roused



He's a quiet type normally, all wrapped up in productivity. But when his production line is brought to a standstill by the premature failure of a furnace element, in he rushes to the Buyer's Office. 'Look at this element' he says, and then it starts . . . .

It's little use for the Buyer to protest that he only orders the elements—Mr. Finch is formidable in this mood and, of course, he's right. Correct choice of the most suitable resistance material would have ensured dependability and long life. That is why so many furnace manufacturers use one of the Brightray Alloys for their elements.

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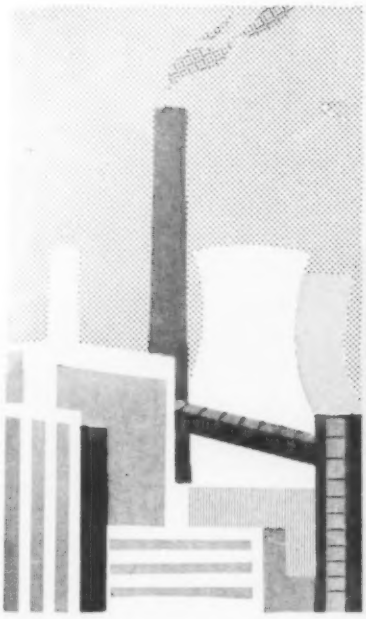

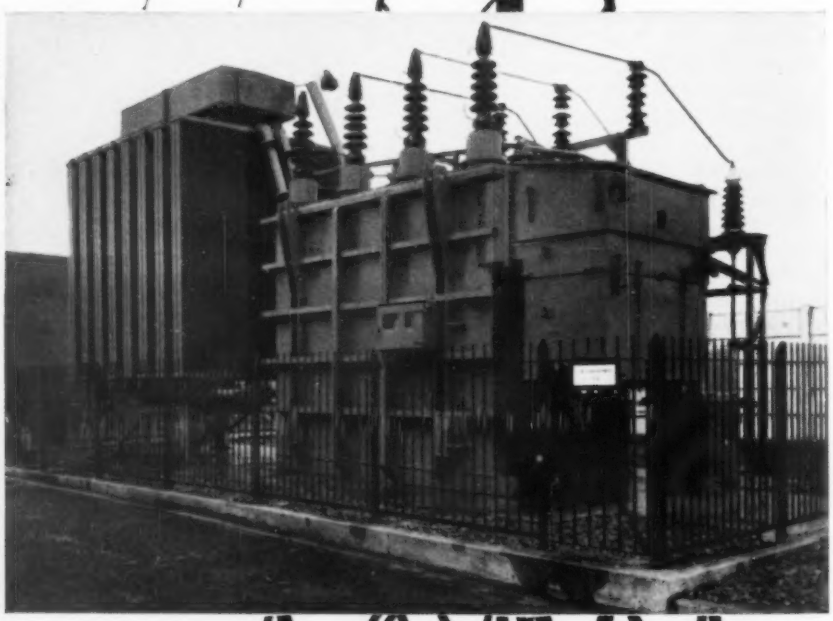

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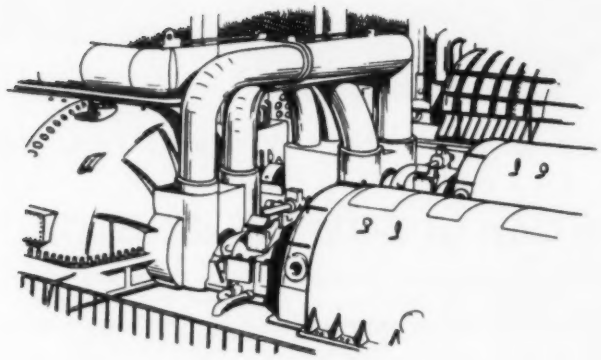

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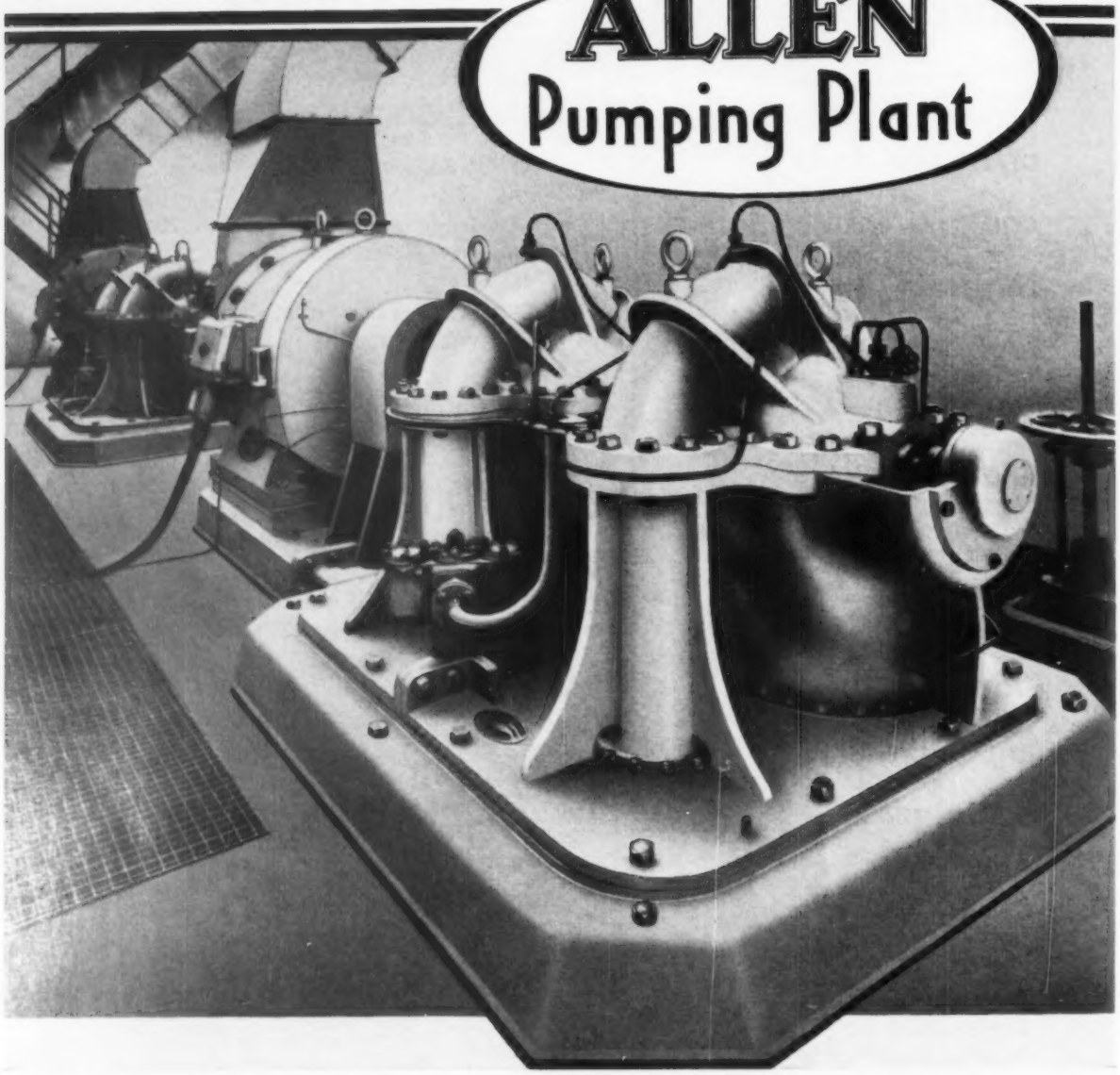

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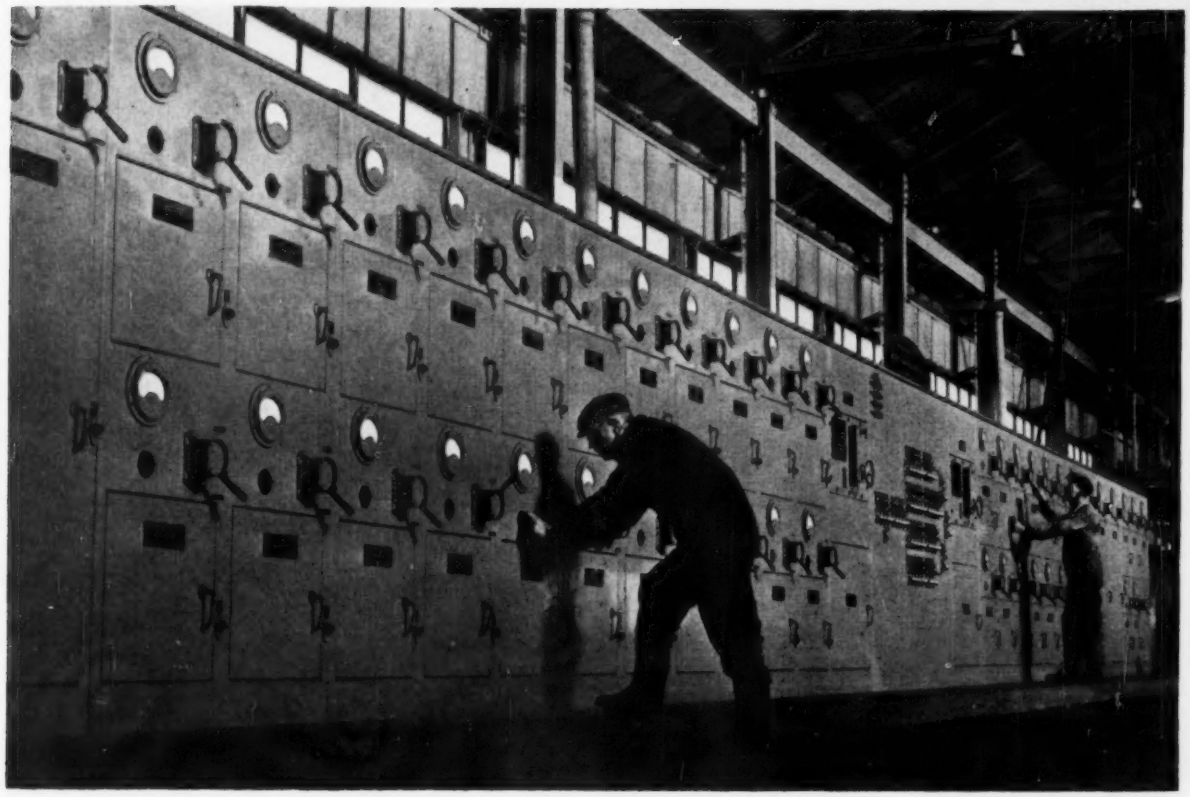

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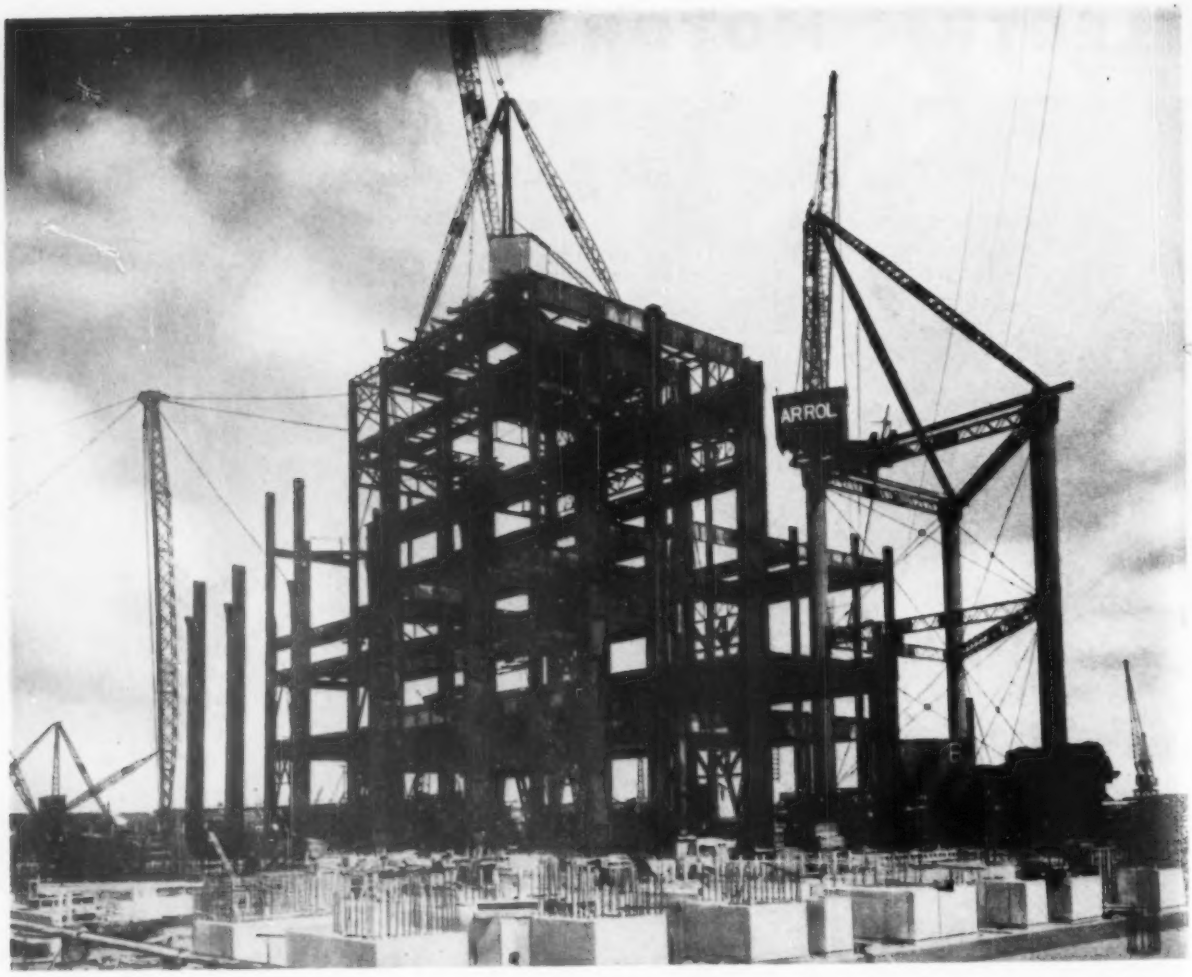

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